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VALIDATION TESTS IN BUILDING 327 — 50-POUND BOMBPROOF

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RESEARCH AND TECHNOLOGY DEPARTMENT

30 OCTOBER 1985

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This report presents the results of a group of validation tests conducted on the new 50-pound blast chamber, NSWC/WO Building 327. An initial series of nine shots, ranging in weight from 1 to 50 pounds of TNT, were fired. (Subsequently, two additional shots, weighing 20 and 43 pounds of TNT, were also fired. These two additional shots are also partly reported herein.) Measurements were made on chamber wall displacement, strain levels in the chamber walls, floor motion in the work area, sound levels both in the work

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20. Abstract (Cont.)

area and outside the building, and carbon monoxide levels in the work area.

It was found that charges weighing 30 pounds or more produced high concentrations of carbon monoxide in the work area. Sound levels in the control room were no higher than 115 dB peak flat sound pressure level. Pressure levels outside the building were also in the acceptable range. The floor motion seemed to go through a resonance of between 40 and 80 Hz, depending on the charge size. The quasi-static pressure levels agreed well with predicted values. Keywords

FOREWORD

This task was performed for the Energetic Materials Division of the Naval Surface Weapons Center, White Oak Laboratory.

The authors wish to acknowledge the following people for their help in the performance of this task: R. Bendt for pre-test predictions and test planning, V. Moore for test execution, G. Klompenhouwer for data reduction, E. Green for gas measurements, P. Spahn for his help in test planning, and C. Goode for test execution.

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Approved by:

Charles Dickinson

CHARLES DICKINSON, Acting Head
Energetic Materials Division

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CHAPTER 1

INTRODUCTION

A new explosive test facility, Building 327, was recently completed at the Naval Surface Weapons Center, White Oak. This facility features a massive steel-lined, reinforced concrete blast chamber to confine the effects of the detonation of up to 50 pounds (TNT equivalent) of explosive. The inside dimensions of the chamber are 20' x 20' x 16'; the floors, walls, and roof are 5 to 7 feet thick, also of reinforced concrete. The chamber has a large steel access door. Figures 1-1, 1-2, and 1-3 show top and side views of the building.

The building is located within the explosives area (300 Area) of the White Oak facility. Figure 1-4 shows an overall layout of the 300 Area and the specific location of the Building 327 Complex in relation to its surrounding buildings.

VALIDATION TESTS, BUILDING 327

Before the new facility could be placed into operational use, it was decided that a series of validation tests would be performed. These tests were designed with several functions in mind:

1. To determine if the building could, indeed, safely contain the effects of the detonation of up to 50 pounds TNT equivalent.

2. To determine if the detonation of materials within the blast chamber produced any adverse effects, either on personnel or equipment contained within the facility.

3. To determine if the building performed as it was designed to perform.

4. To determine, as far as possible, if the detonation of materials within the blast chamber produced any adverse effects on the environment surrounding the building.

With these goals in mind, a series of TNT charges with weights ranging from 1 to 50 pounds were detonated and their effects in, on, and around the building were measured. The TNT charges were right circular cylinders, placed on a wooden table 4 feet above the floor in the center of the blast chamber. Table 1-1 presents the firing order of the charges used.

The measurements undertaken included strain in the exterior walls of the chamber, wall displacement, floor motion, carbon monoxide levels, internal pressure within the blast chamber, and sound pressure level both inside the building and at several locations external to the building.

Subsequent to the completion of the primary validation testing, additional shots were fired. These were not, per se, validation tests. They were designed to determine the chamber efficiency and to measure the gas content and concentration both within the chamber and outside in the atmosphere. These results will be reported separately. However, as part of these two tests, internal pressure and temperature measurements were also undertaken.

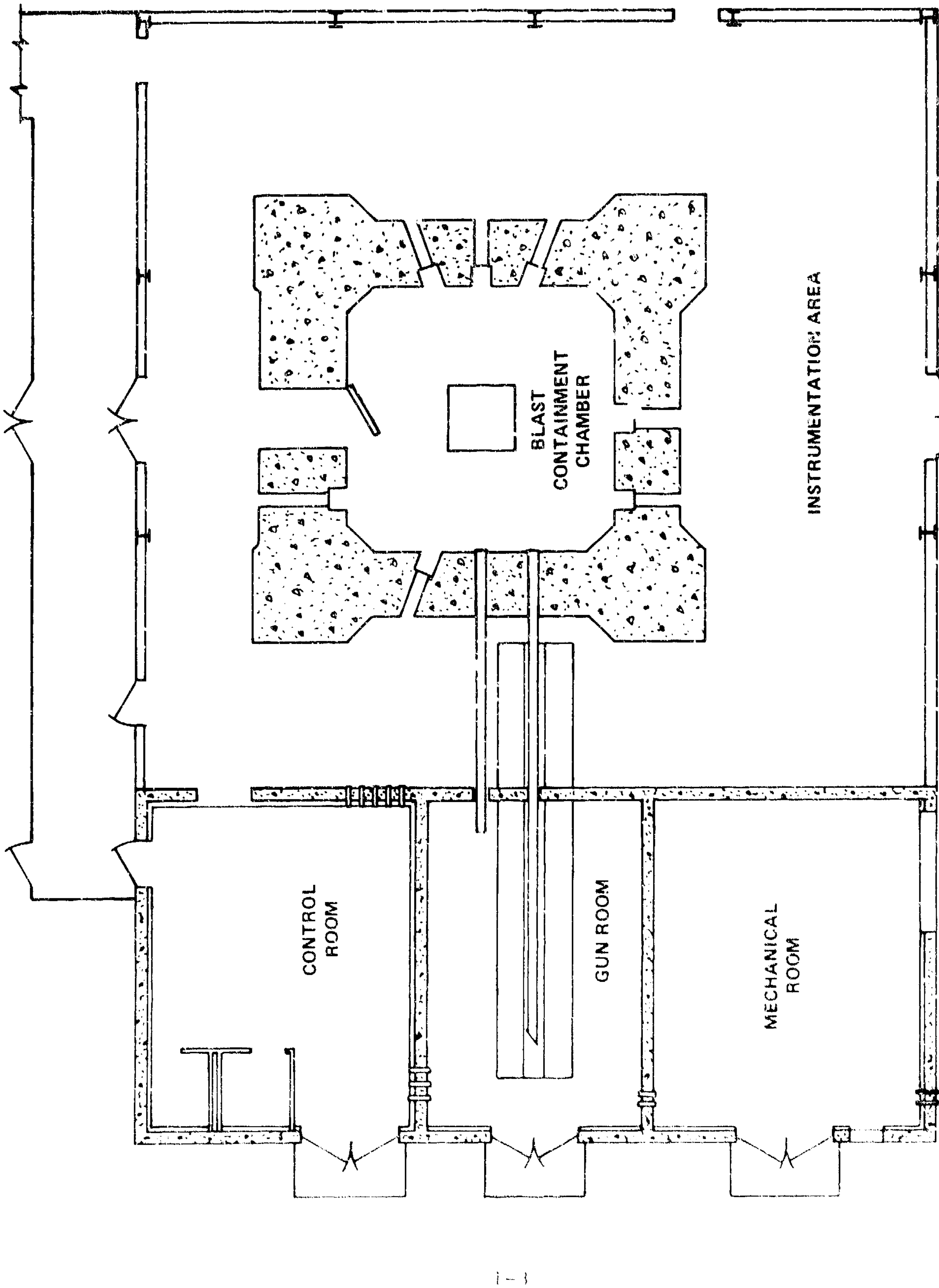


FIGURE 1-1. BUILDING 327, TOP VIEW

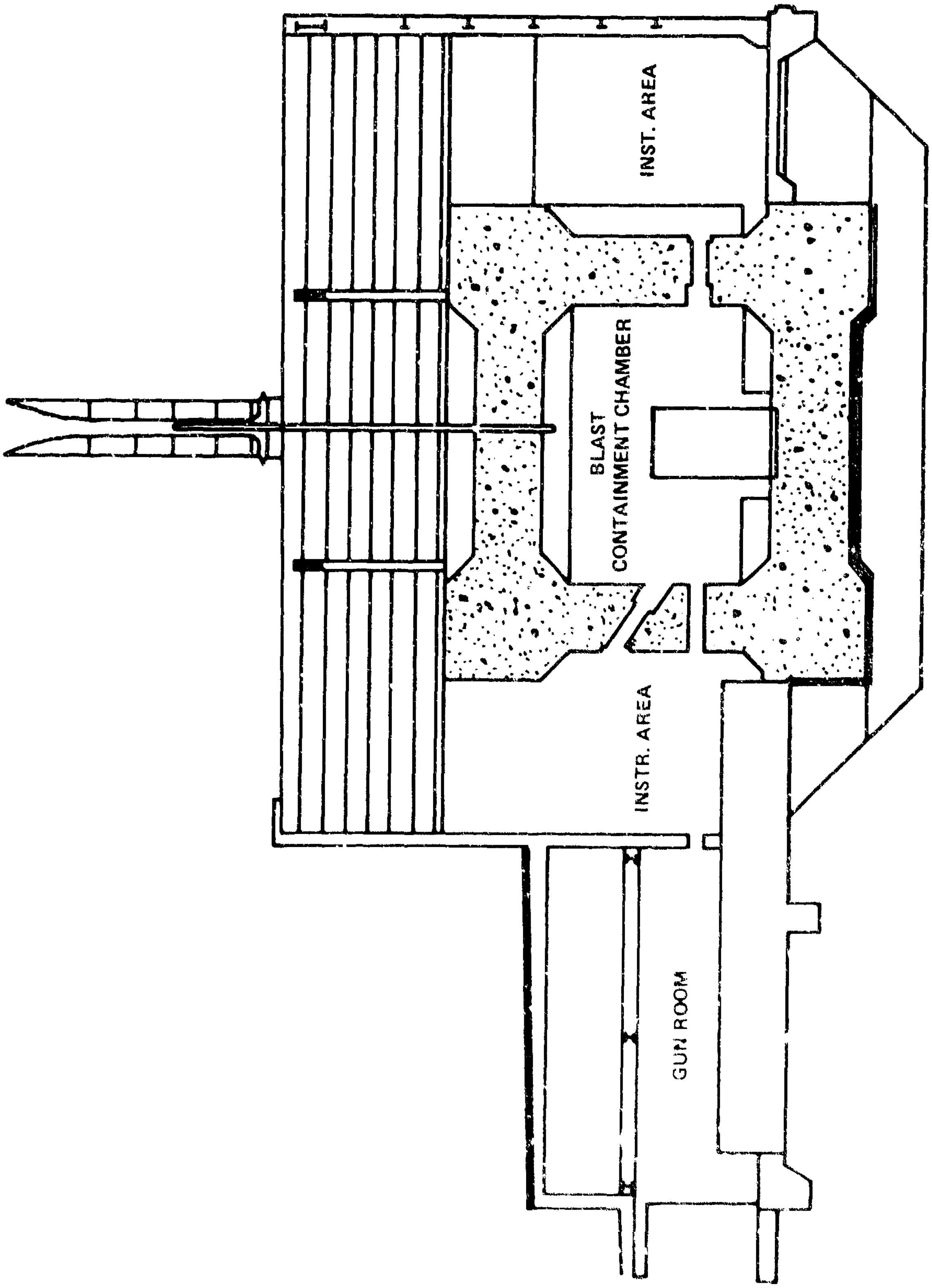


FIGURE 1-2. BUILDING 327, SIDE VIEW, EAST

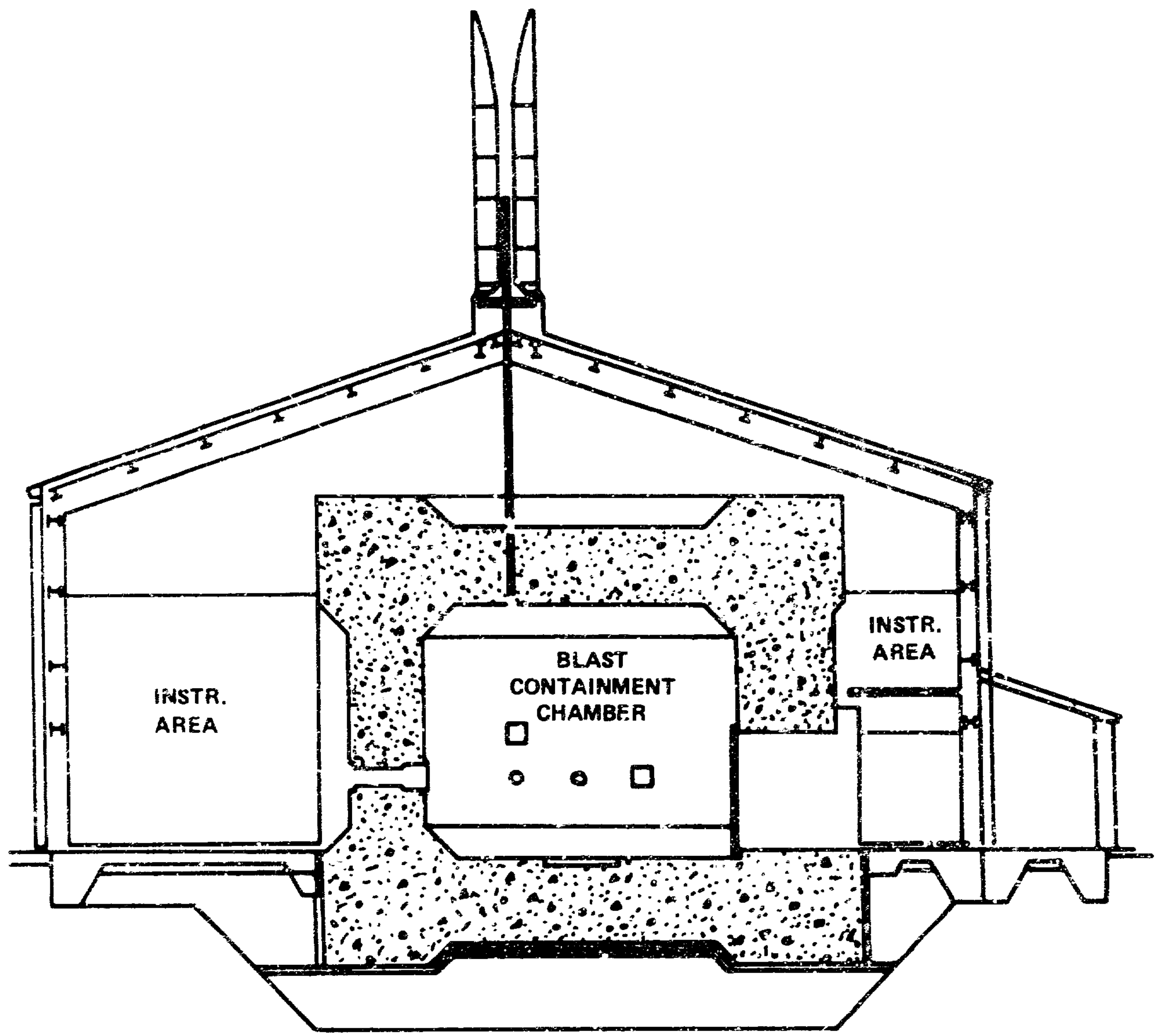


FIGURE 1-3. BUILDING 327, SIDE VIEW, NORTH

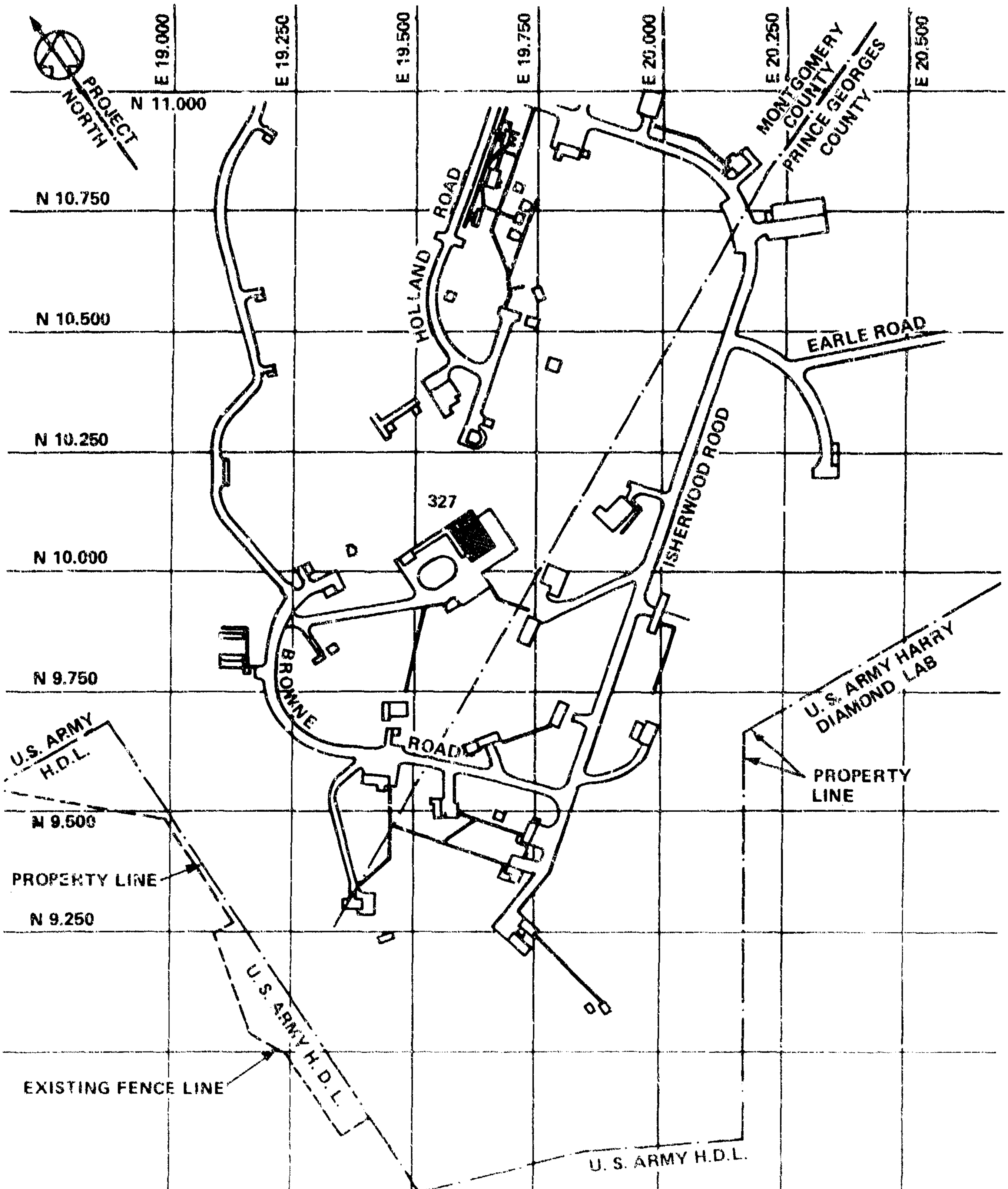


FIGURE 1 4. 300 AREA

TABLE 1-1. FIRING ORDER OF TNT CHARGES

SHOT NUMBER	EXPLOSIVE* WEIGHT (lb)	SHOT TIME[1] D	: H	: M	: SEC	: MSEC
2302	1	348	14	25	03	363
2303	1	352	11	14	10	806
2304	2	358	13	27	41	646
2305	5	358	NO ZERO TIME			
2306	10	358	10	18	08	952
2307	10	358	13	38	55	088
2308	20	358	14	43	44	432
2309	30	359	09	59	26	568
2310	50	359	13	02	59	170
2444**	20.7	277	15	05	15	769
2445**	43.6	281	11	20	46	289

* Note all charges were TNT

**Additional tests fired in September 1985.

[1] Shots 2302 through 2310 were conducted during 1984; shots 2444 and 2445 were conducted in 1985.

CHAPTER 2

INSTRUMENTATION

GENERAL

Since an examination of the response of the blast chamber was of primary interest, a variety of gauges and gauge types had to be used. The effects of interest were quasi-state pressure in blast chamber, wall displacement, strain in the walls and blast chamber door, floor motion, sound level, acceleration of the door, and carbon monoxide gas concentration. These effects were measured from a series of explosive charges weighing from 1 to 50 pounds. The sensors were apportioned as follows:

3 quasi-static pressure gauges

4 displacement gauges

8 strain gauges

1 (3-channel) floor motion gauge

3 low pressure airblast (sound pressure level) gauges

1 accelerometer

1 peak reading sound level meter

2 carbon monoxide detectors

QUASI-STATIC PRESSURE

Kulite Model HKM-375

This is a miniature pressure transducer having a 17-4 stainless steel diaphragm unit using an integrated sensor as its sensing element. The sensor is an inorganically-bonded, piezo-resistive active half bridge. A series of 500-psi gauges, rated to 750 psi, having an output of 0.167 mV/psi, were used. These gauges were mounted in plates located on the inside walls of the blast chamber. Each was recessed to accommodate a socket head set screw (see Figure 2-1). The gauge was centrally drilled with a #55 drill and screwed into the gauge interior orifice of the gauge port. These gauges were conditioned from a Pacific Model 8250 signal conditioning unit.

DISPLACEMENT

Schaevitz LVDT Type GCA-121-250

This is an hermetically sealed, ac-operated linear variable differential transformer (LVDT). Its nominal linear range is ±0.250 inch having a sensitivity of 1.6 mv per volt per .001 inch. These gauges were calibrated in place prior to the first test. Each gauge was mounted to minimize vertical vibration and positioned to measure the displacement of the outer steel plates of the blast chamber wall. The gauges were conditioned with Schaevitz CAS series LVDT signal conditioners.

STRAIN GAUGES

Measurements Group, Inc. ED-DY-40CBY-350

This type of strain gauge is an open-faced, general purpose gauge using an isoelastic alloy. It has a high gauge-factor (3.75) and high fatigue life. These gauges were mounted on the outer concrete wall of the blast chamber by a qualified representative from the Micro-Measurements Division of Measurements Group, Inc. (see Figure 2-2(a)). Figure 2-2(b) shows the vertical and horizontal orientation used on three walls of the blast chamber. A similar orientation was used on the inner face of the blast chamber door. These gauges were conditioned by B & F Instruments, Inc., Model 702A-10D differential amplifier and Model 1-700SG input conditioner.

FLOOR MOTION

Vibra-Metrics Model 320

Floor motion measurements were made with a single triaxial velocity gauge, Vibra-Metrics, Inc., Model 320. This is a self generating system with an output of a nominal 100 mv per inch per second. Signals were fed into an amplifier with a gain of 10 and then recorded on a Honeywell 101 recorder.

The gauge was placed on the floor, 3 feet from the north wall of the blast chamber in the work room. It was centered on the center viewing port (see Figure 4-1).

ACCELERATION

RION Co. PV-90A

The PV-90A is a piezoelectric accelerometer with a charge sensitivity of 2.1 pc/g. The gauge was mounted on the back (outer) face of the blast chamber door. A RION Co. charge amplifier, Model VM-27, was used to condition the output signal.

SOUND LEVEL

Endevco Model 8550M1

The Endevco Model 8550M1 is a miniature piezo-resistive microphone designed for measuring high-intensity sound. This is a four-active-arm Wheatstone bidge that provides a capability for measurement from static pressure throughout the normal audio frequency range. The typical output of the gauge is 218 mV/psi. Gauges were mounted in a plywood baffle whose dimensions were 3' x 3' which was located 1' off the floor and conditioned with the Pacific Model 8250 conditioning unit.

Bruel and Kjaer Type 4147/2631 Microphone System

A Bruel and Kjaer (B&K) Type 4147 1/2-inch condensor microphone was used with a B&K Type 2631 10 MHZ FM carrier system. This combination gives wide frequency response (1 HZ to 16 KHZ) and excellent sensitivity (approximately 200 V/psi). Its output was recorded directly on magnetic tape.

GENRAD Model 1982 Precision Sound Level Meter and Analyzer

Peak holding GENRAD Model 1982 Precision Sound Level meters were also used. These were used on the "peak, flat" settings. A digital read-out gave the maximum sound pressure level encountered since the meter was previously reset.

CARBON MONOXIDE (CO) CONCENTRATION

Ecolyzer Model 2000 and Gas-Tech Model CO-80

The CO levels were measured by two Ecolyzer Model 2000 monitors that put out a linear signal proportional to the CO levels. The CO monitors were calibrated with a standard gas bottle that contained a gas mixture of 50 ppm of CO. The Ecolyzers were connected to a Bell and Howell Model 5-144 Visicorder that was used to record the CO levels detected. One Ecolyzer CO monitor was stationed in front of the blast chamber door in the work room and the second CO monitor was stationed inside the control room by the cable ports that connected the control room with the work room. Hand-held Gas Tech Model CO-80 carbon monoxide monitors, with an audio alarm set to go off when the CO levels exceeded 50 ppm, were used to check the CO levels in the blast chamber and work room.

SIGNAL CONDITIONERS

Model 1-700 Input Conditioner

The input conditioner provided the necessary regulated voltage to power the strain gauge, balancing circuits, and provisions for shunting the bridge for calibration.

Model 702A-10 Differential Amplifier

The bridge output was amplified by a factor of 1 to 500 depending on the charge weight tested. The output of the amplifier was wired for single-ended input for reading an analog tape recorder.

Pacific Model 8250

The 8250 signal conditioning amplifier provided excitation, balance, calibration, and amplification for strain and pressure gauges. The amplifier bandwidth is 100 kHz and signal conditioning used auto-balance on the input signal. The output was wired for single-ended input Ampex for analog recording.

LVDT CAS Series

The Schaevitz CAS-025 high gain LVDT signal conditioner is fully self-contained and line powered, so that connecting an LVDT-type transducer and readout results in a complete system. The output was recorded on magnetic tape.

VM-27 Charge Amplifier

The Model VM-27 is a charge amplifier for a piezoelectric accelerometer. The unit functions as a complete system for calibration/measurement of acceleration/ vibration. The output was recorded on magnetic tape.

DATA RECORDING/ANALYSIS

Ampex FR1300 Magnetic Tape Recorder

All conditioned transducer signals, calibration steps, and strain and displacement records were recorded at 60 ips tape speed on FM channels; 20 kHz frequency response is available in this mode of operation. Playbacks of the analog signals for a quick-look evaluation were made on a Nicolet Model 3091 digital storage scope. Timing was obtained by recording IRIG A from a Datachron Time Code Generator. Figure 2-3 gives instrumentation diagram for the FR1300 system.

Honeywell 101 Magnetic Tape Recorder

Conditioned transducer signals, calibration steps, quasi-static pressure, acceleration, sound level, and floor motion records were recorded at 60 ips tape speed on FM channels (WBI). This gave a 80 kHz frequency response in this mode of operation. Playbacks for a quick-look evaluation were made on a Nicolet 3091. Timing was obtained by recording IRIG A. Figure 2-4 gives the instrumentation diagram for Honeywell 101 system.

Data Reduction

Analog tape records were digitized with the R15 Data Reduction System and computer processed readouts were analyzed for interpretation of blast chamber effects.

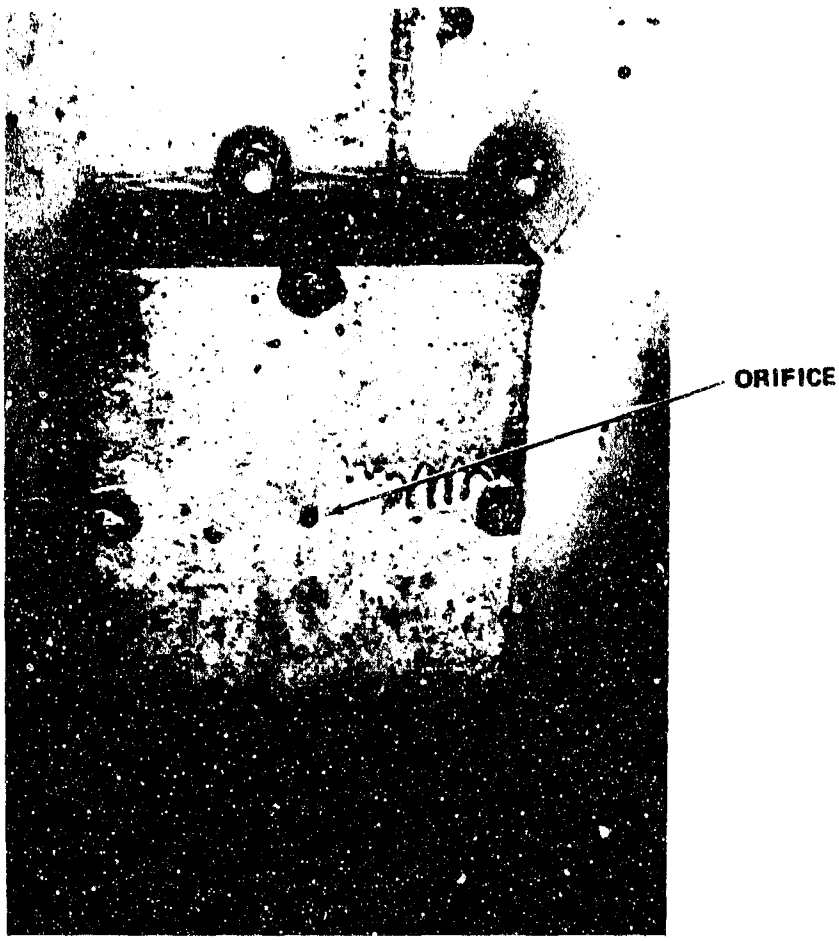
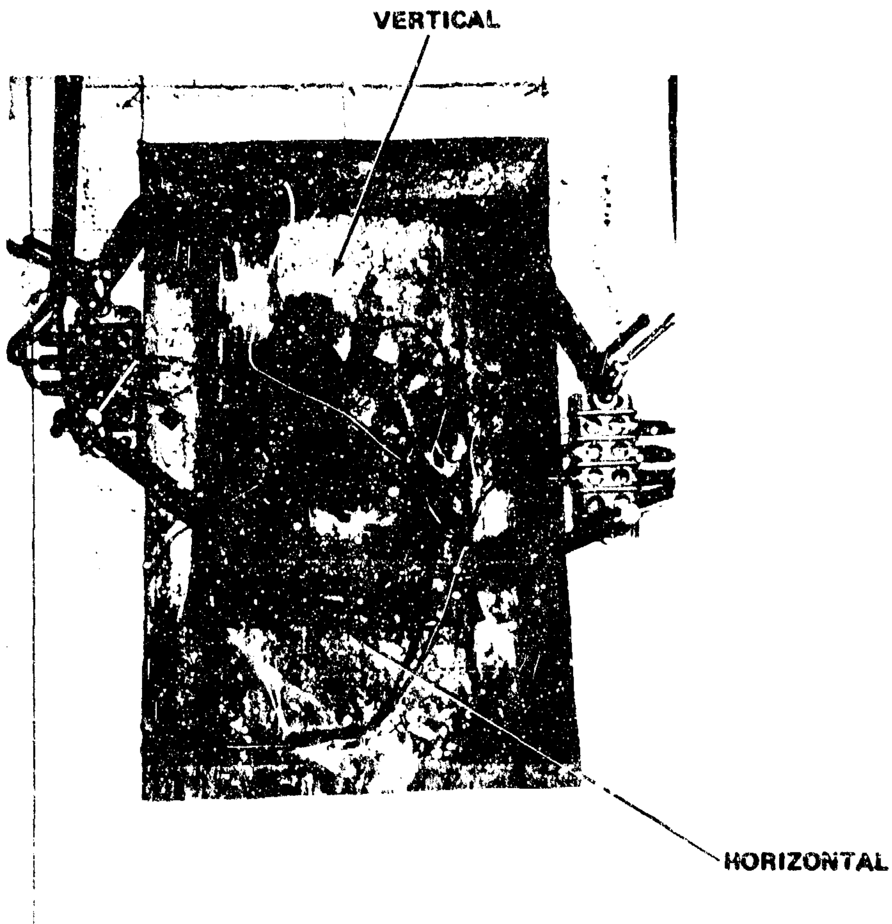


FIGURE 2-1. QUASI-STATIC PRESSURE GAUGE MOUNT

(a) ED-DY-40CBY-350 GAUGE



(b) MOUNTED GAUGE

FIGURE 2-2. STRAIN GAUGE

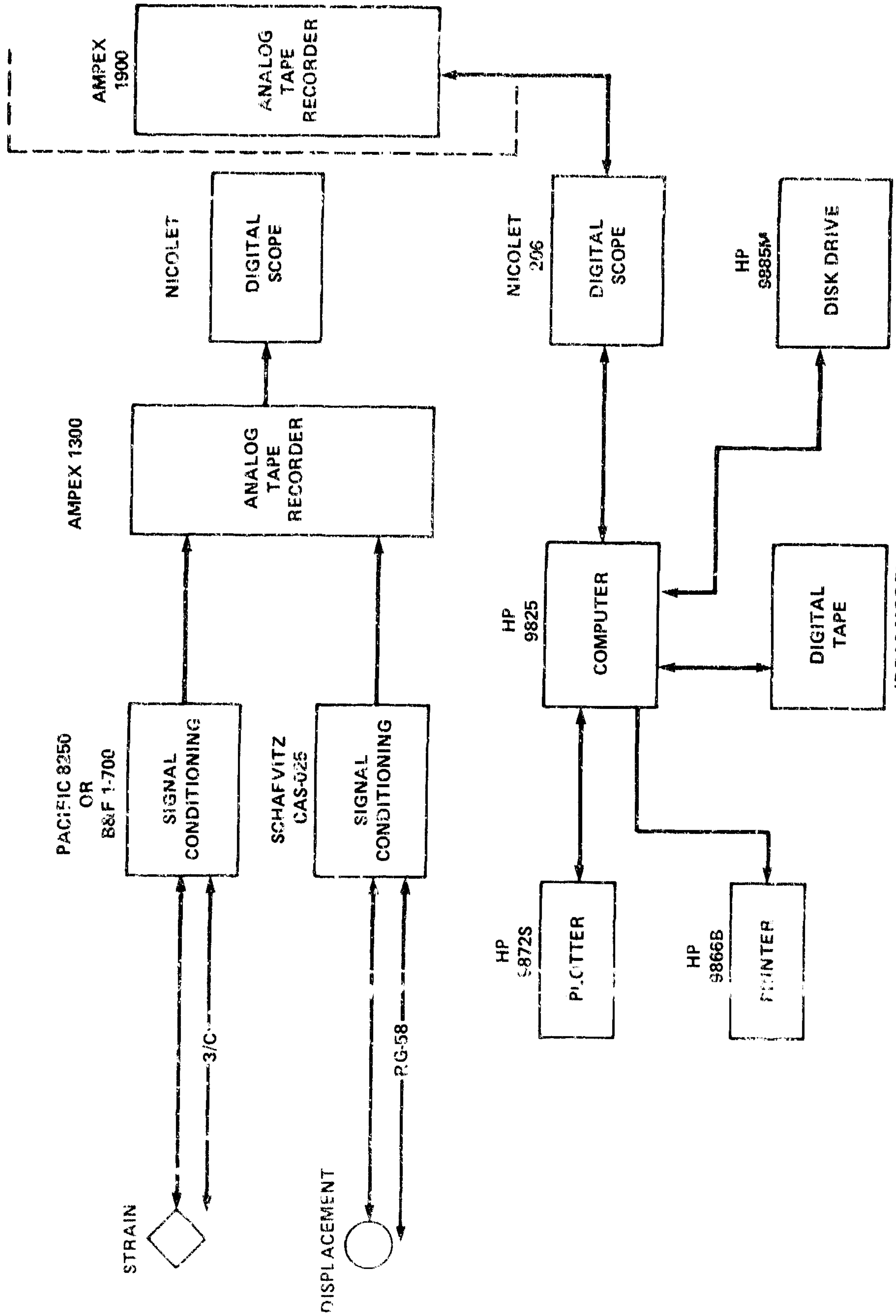


FIGURE 2-3. SIGNAL FLOW CHART FOR #1 RECORDER

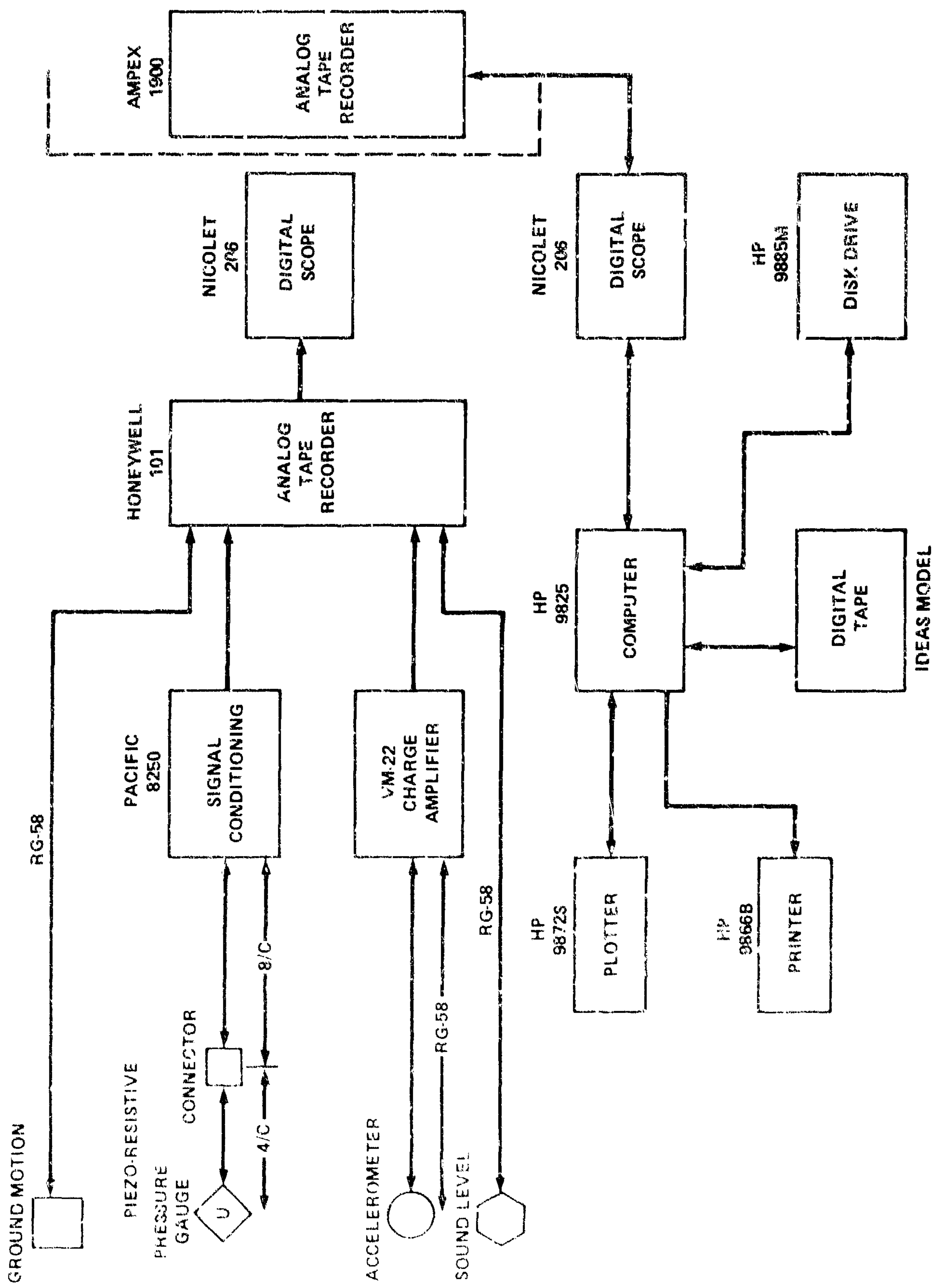


FIGURE 2-4. SIGNAL FLOW CHART FOR #2 RECORDER

CHAPTER 3

DISPLACEMENT

The four displacement gauges were capable of measuring ±0.250 inch of the movement of the outer steel plate of the Blast Chamber wall. Figure 3-1 shows the position of each gauge. Table 3-1 presents the maximum and minimum displacement measurements recorded at each gauge position. Appendix A gives the displacement-time (d-t) histories for each shot. The left column of d-t histories in Appendix A shows the early motion of the wall and the right column shows the total duration (late motion histories) of wall motion.

The records of the first three shots (1 and 2 pound TNT) were just above the system noise level. The range of measurements was from ±0.002 to 0.008 inch, (the accuracy of the gauge is ±0.001 inch). Figures 3-2 to 3-5 present the maximum displacement versus explosive weight of north, east, south, and west wall positions, respectively. Figure 3-6 shows a composite plot of maximum displacement versus explosive weight. For the 5-pound charge, the displacement range was 0.004 to 0.010 inch. For the 10-pound TNT tests, the wall displaced 0.006 to 0.037 inch. The 20-pound charge gave a 0.047 to 0.056 inch displacement spread. The 30-pound tests were lower than the 20-pound tests, 0.026 to 0.053 inch. The last test, 50-pound TNT charge, produced the most deflection, 0.053 to 0.068 inch. Pre-test predictions for the wall deflections had indicated a maximum deflection on the order of 0.05 inch.

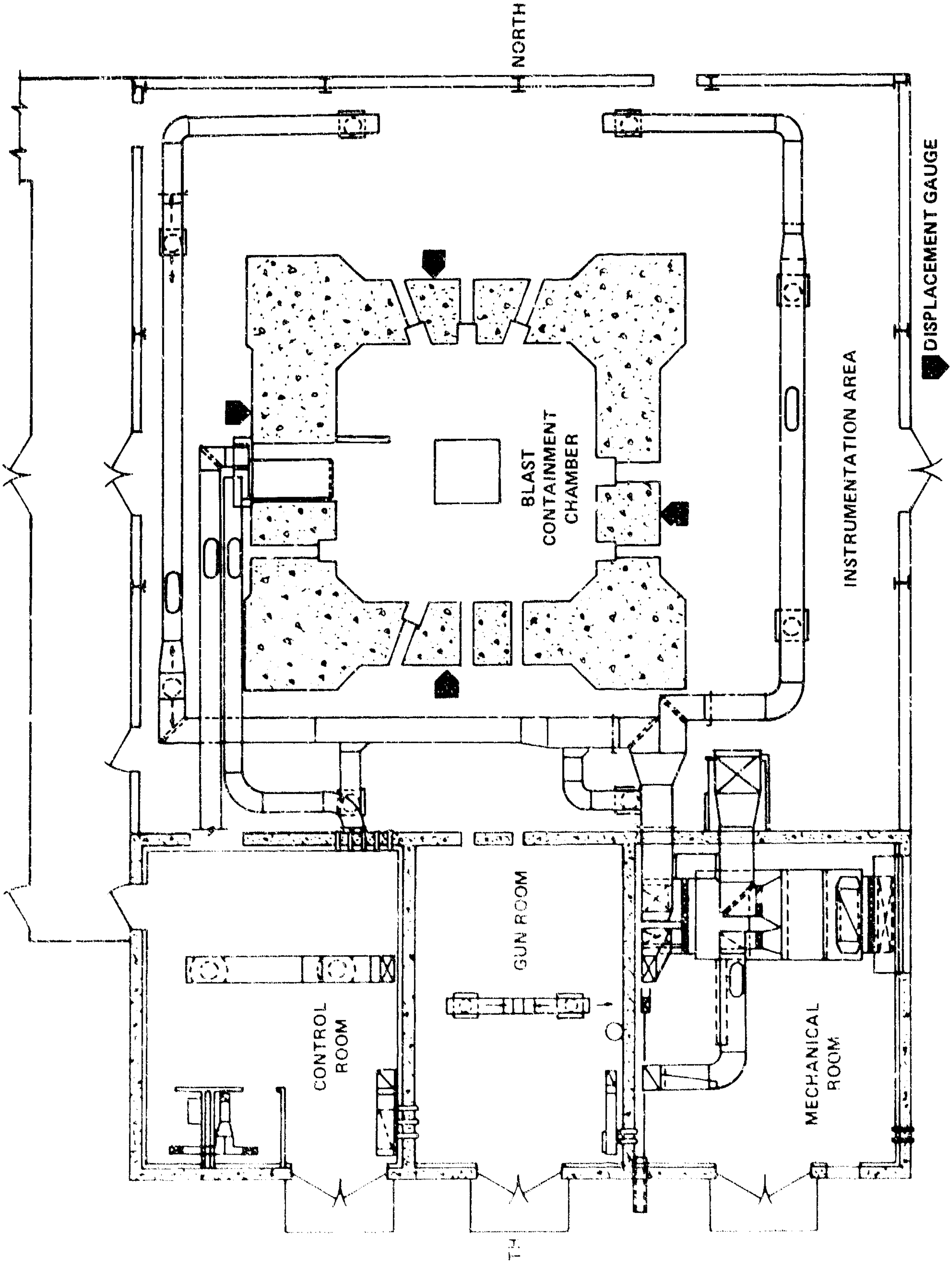


FIGURE 3-1. LOCATION OF DISPLACEMENT GAUGE

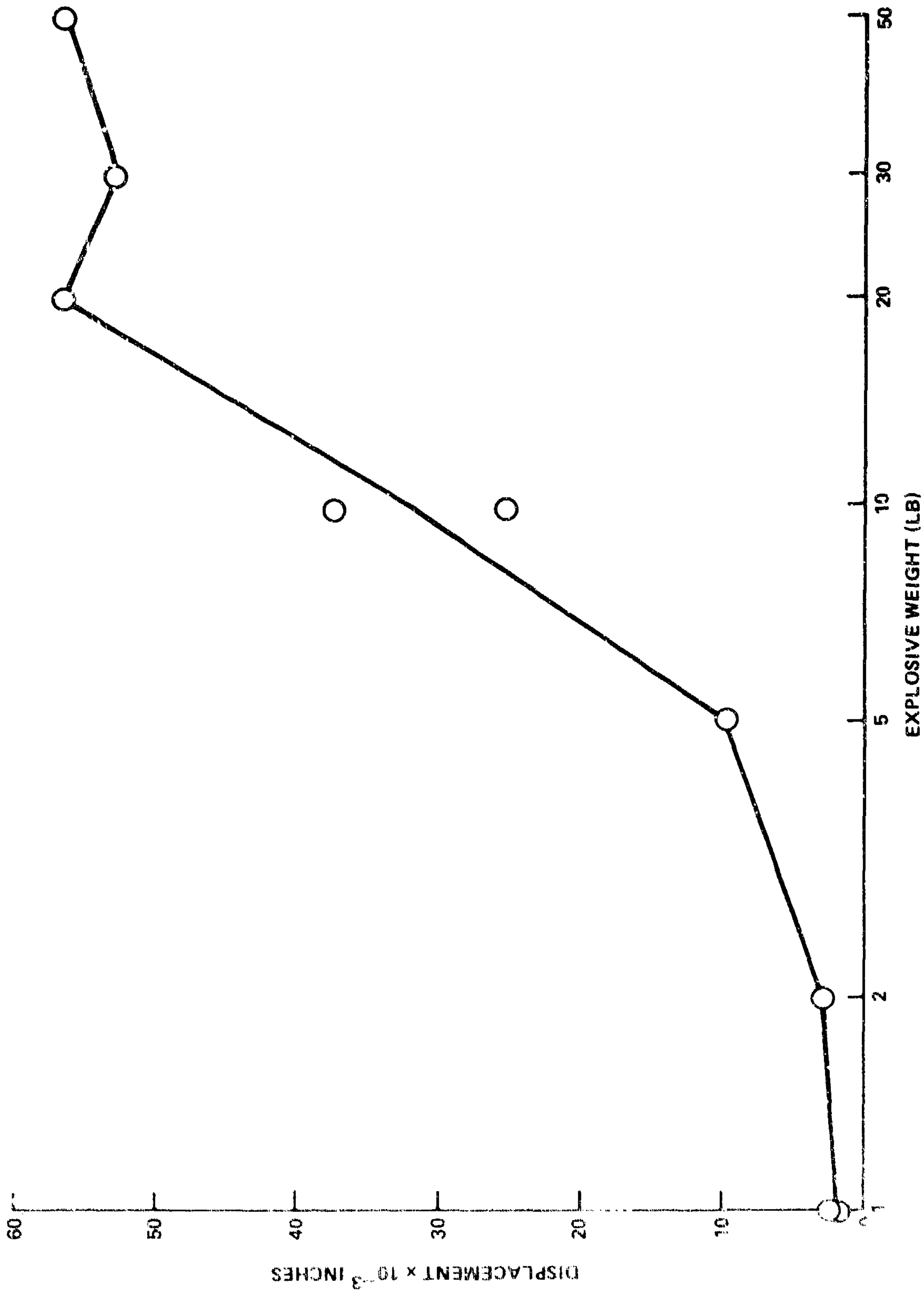


FIGURE 3-2. MAXIMUM DISPLACEMENT VERSUS EXPLOSIVE WEIGHT, NORTH WALL

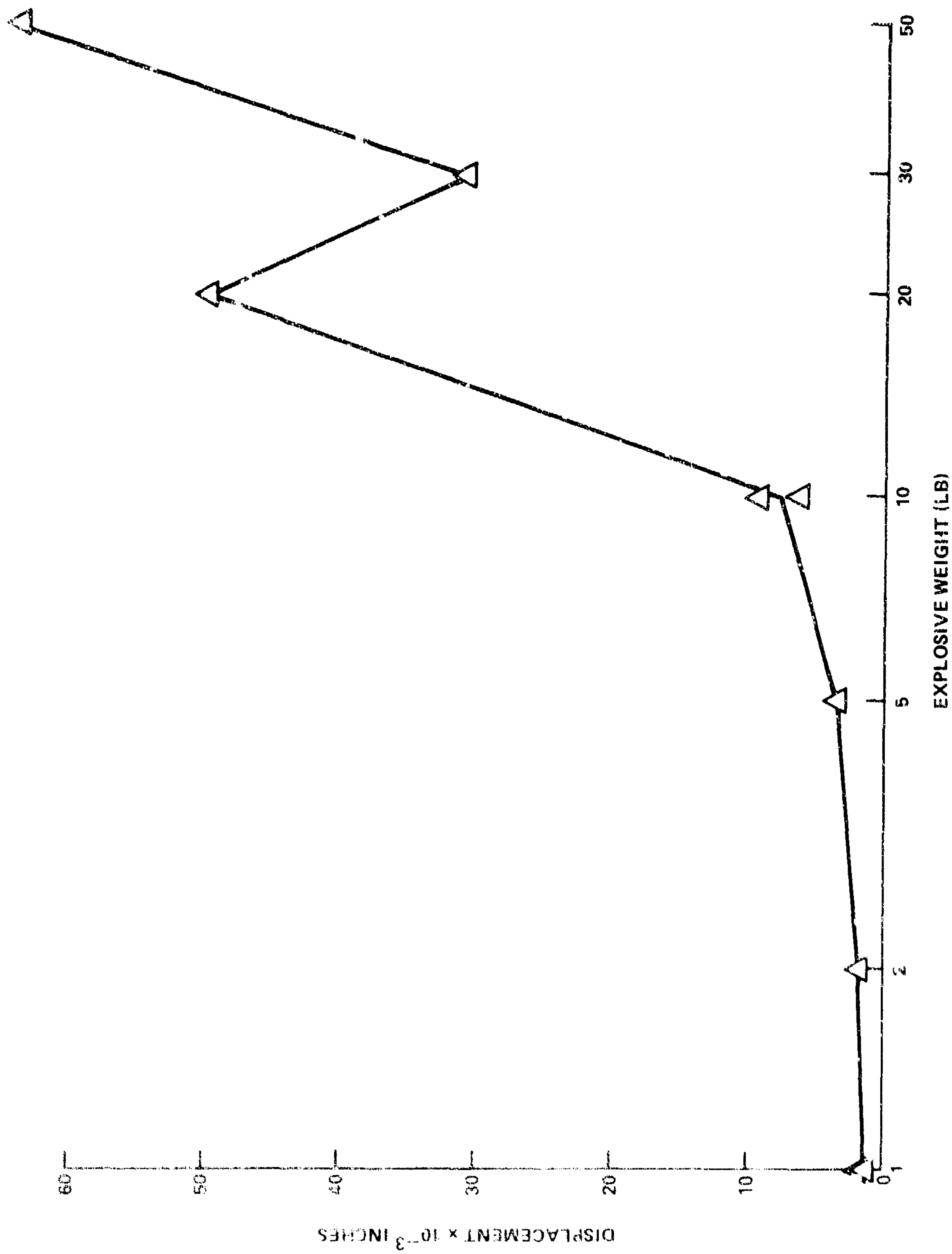


FIGURE 3-3. MAXIMUM DISPLACEMENT VERSUS EXPLOSIVE WEIGHT, EAST WALL

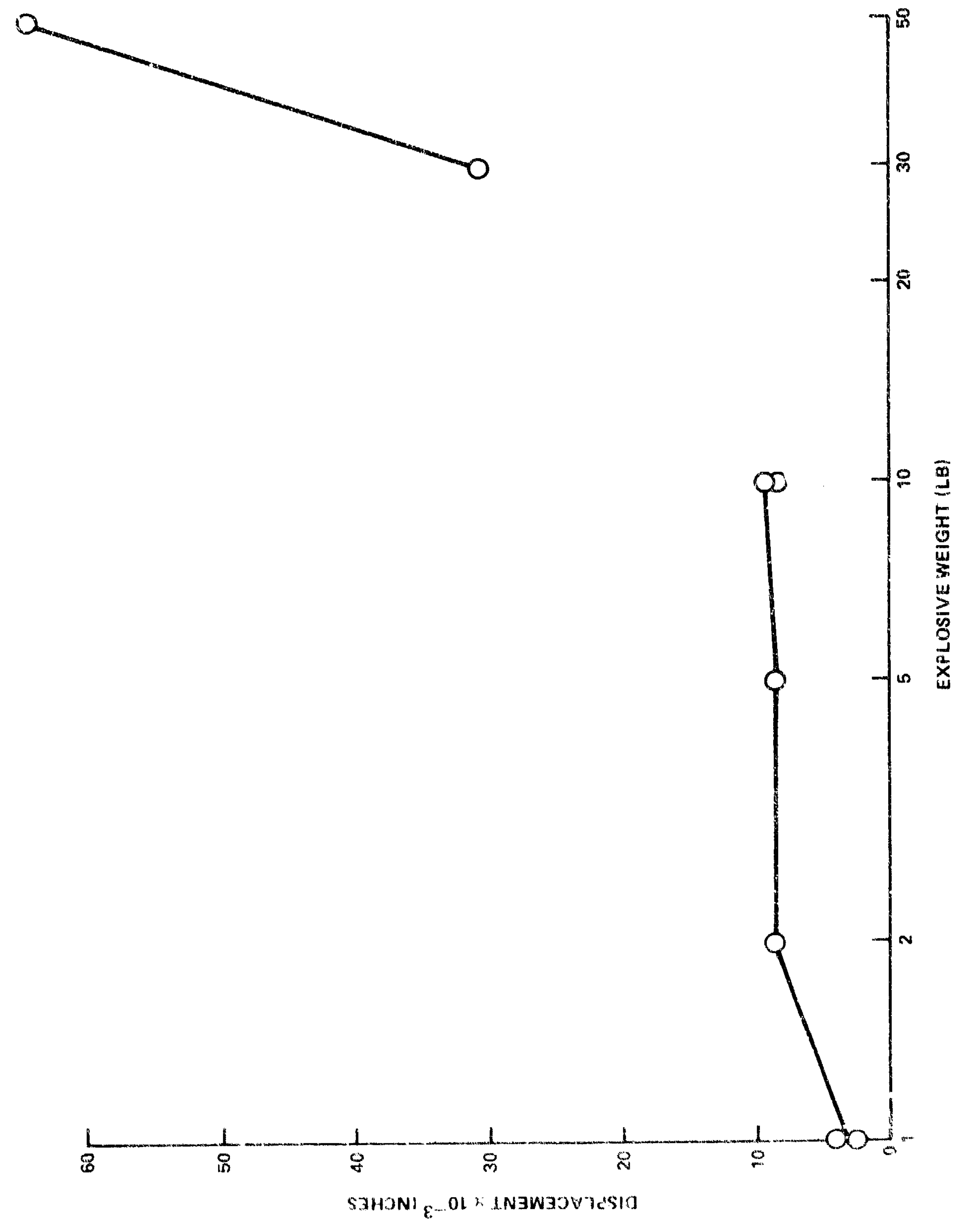


FIGURE 3-4. MAXIMUM DISPLACEMENT VERSUS EXPLOSIVE WEIGHT, SOUTH WALL

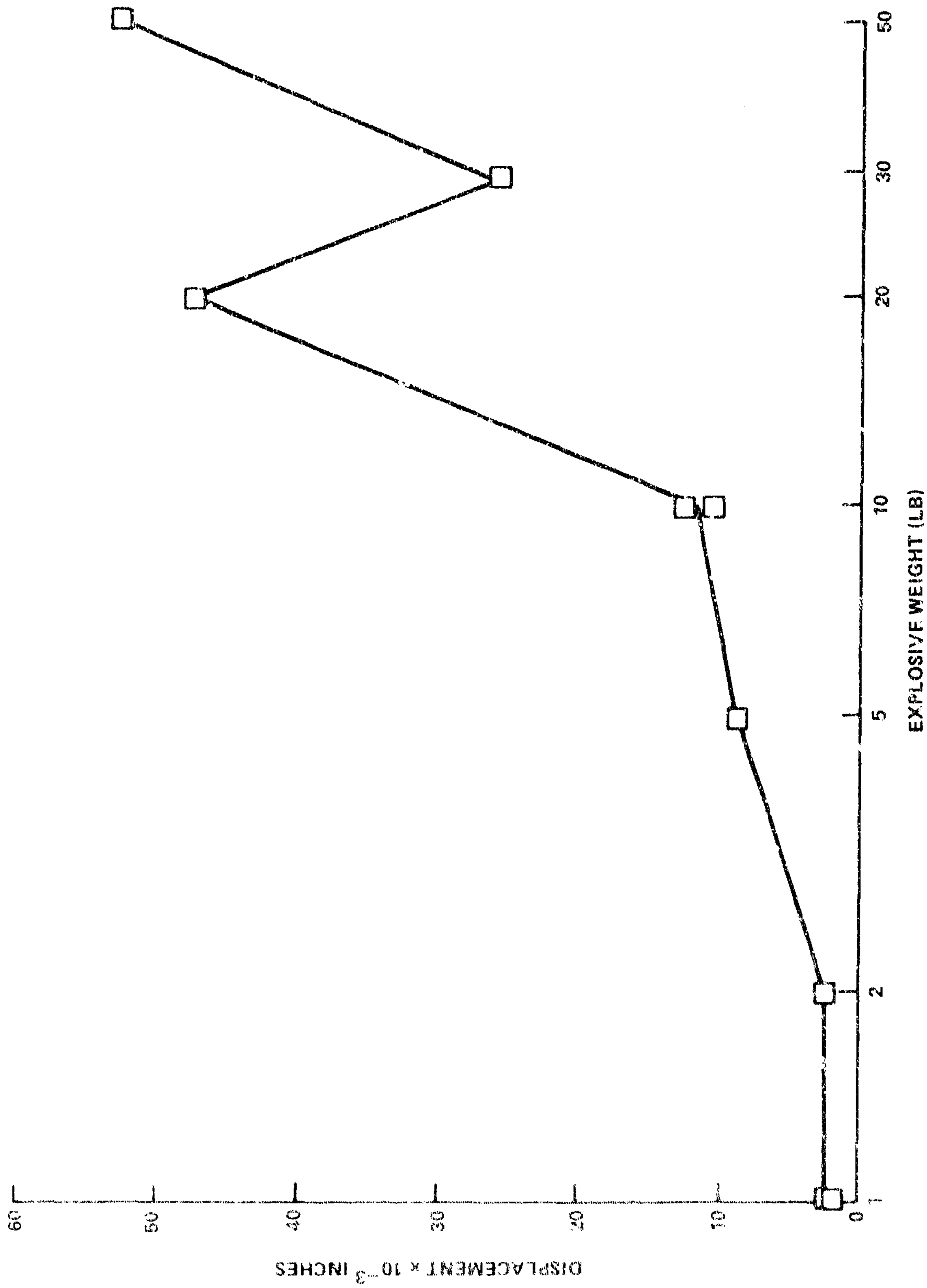


FIGURE 3-5. MAXIMUM DISPLACEMENT VERSUS EXPLOSIVE WEIGHT, WEST WALL

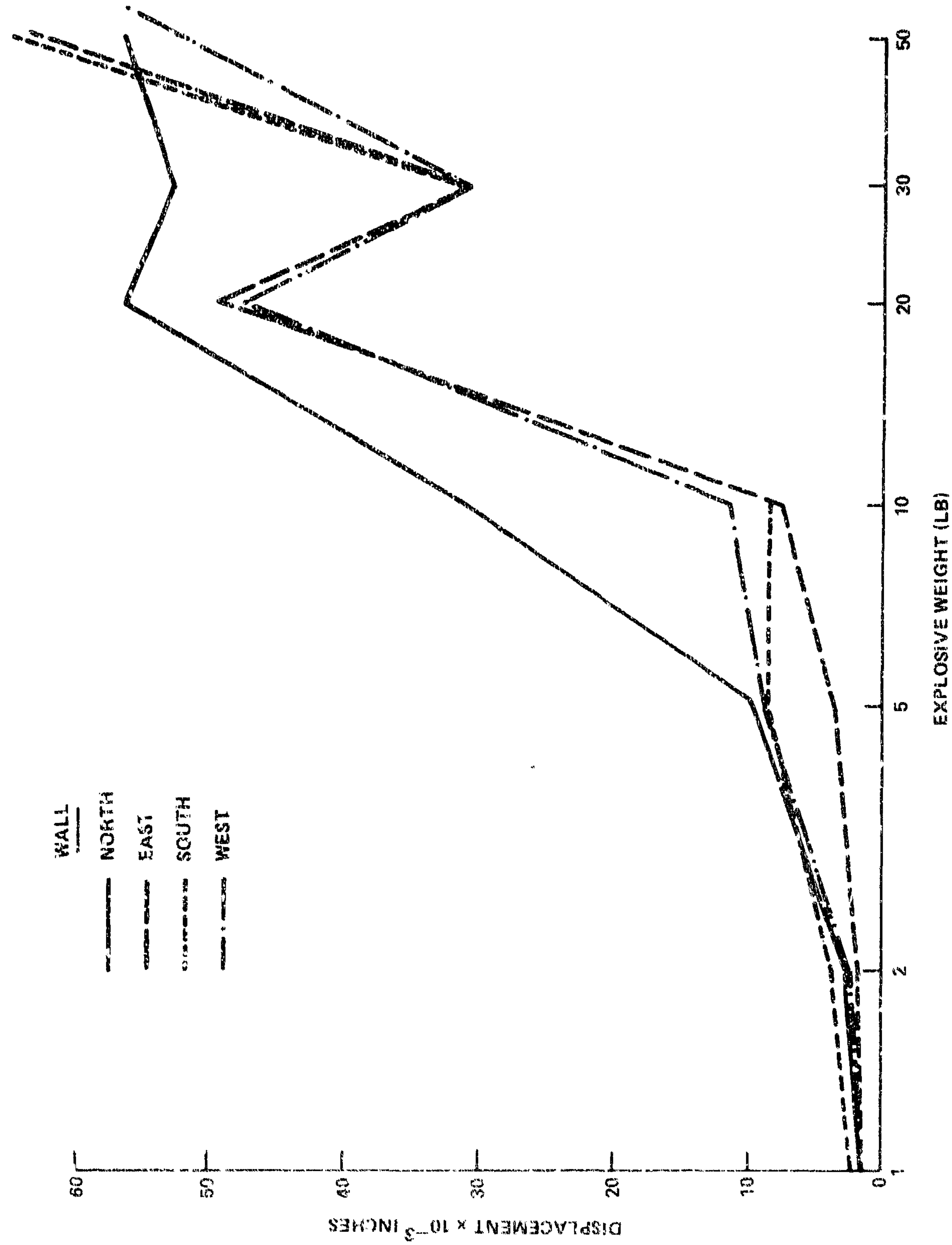


FIGURE 3-6. MAXIMUM DISPLACEMENT VERSUS EXPLOSIVE WEIGHT

TABLE 3-1. WALL DISPLACEMENT DATA

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	POSITION (wall)	MAXIMUM* DISPLACEMENT ($\times 10^{-4}$ inch)	MINIMUM** DISPLACEMENT ($\times 10^{-4}$ inch)
2302	1	NORTH	21	13
		EAST	18	28
		SOUTH	25	19
		WEST	22	26
2303	1	NORTH	16	14
		EAST	16	23
		SOUTH	80	7
2304	2	NORTH	29	25
		EAST	19	24
		SOUTH	40	20
		WEST	24	38
2305	5	NORTH	98	54
		EAST	36	34
		SOUTH	88	20
		WEST	88	44
2306	10	NORTH	253	54
		EAST	61	40
		SOUTH	86	86
		WEST	101	42
2307	10	NORTH	374	83
		EAST	91	72
		SOUTH	80	20
		WEST	125	58
2308	20	NORTH	564	257
		EAST	497	131
		SOUTH	-	-
		WEST	474	78
2309	30	NORTH	529	87
		EAST	308	146
		SOUTH	309	35
		WEST	255	50
2310	50	NORTH	562	247
		EAST	632	176
		SOUTH	647	345
		WEST	527	229

*Displacement outward from rest position.
**Displacement inward from rest position.

CHAPTER 4

FLOOR MOTION

A single (3-component) velocity gauge was placed on the floor 10 feet from the north wall of the blast chamber (see Figure 4-1). Measurements were made in the vertical, transverse (east-west), and radial (north-south) directions. Table 4-1 presents the floor motion data for the three directions for each charge weight. The maximum positive and negative velocities and integrated displacements are given for each shot. Appendix B presents the floor motion-time histories for each shot and its associated frequency spectrum.

Figure 4-2 shows floor velocity versus charge weight. The maximum radial velocity varied very little from shot to shot, 0.08 $\pm$ 0.04 in/sec over the 1 to 50 pound charge range. The transverse direction responded similarly to the radial measurement: 0.15 $\pm$ 0.07 in/sec but with about twice the velocity. Again very little shot-to-shot variation. The vertical floor velocity measurements behaved differently. From 1 to 5 pounds of charge weight, there was very little change, 0.11 + 0.01 in/sec. From 10 to 50 pounds the vertical floor velocity increased with explosive size, 0.3 to 0.7 in/sec, respectively.

Figure 4-3 presents the predominant frequency of the floor motion versus charge weight. The frequency spectrum was calculated for both early- and long-term durations. The average total duration for the floor motion was approximately 2.2 seconds. Both the transverse and vertical measurements of the motion had a major frequency component located between 40 and 80 HZ. The predominant frequency of the radial motion was between 165 and 190 HZ.

The velocity time signals were integrated to determine a displacement-time. The maximum displacement determined in this manner is given in Figure 4-4 as a function of the explosive charge weight.

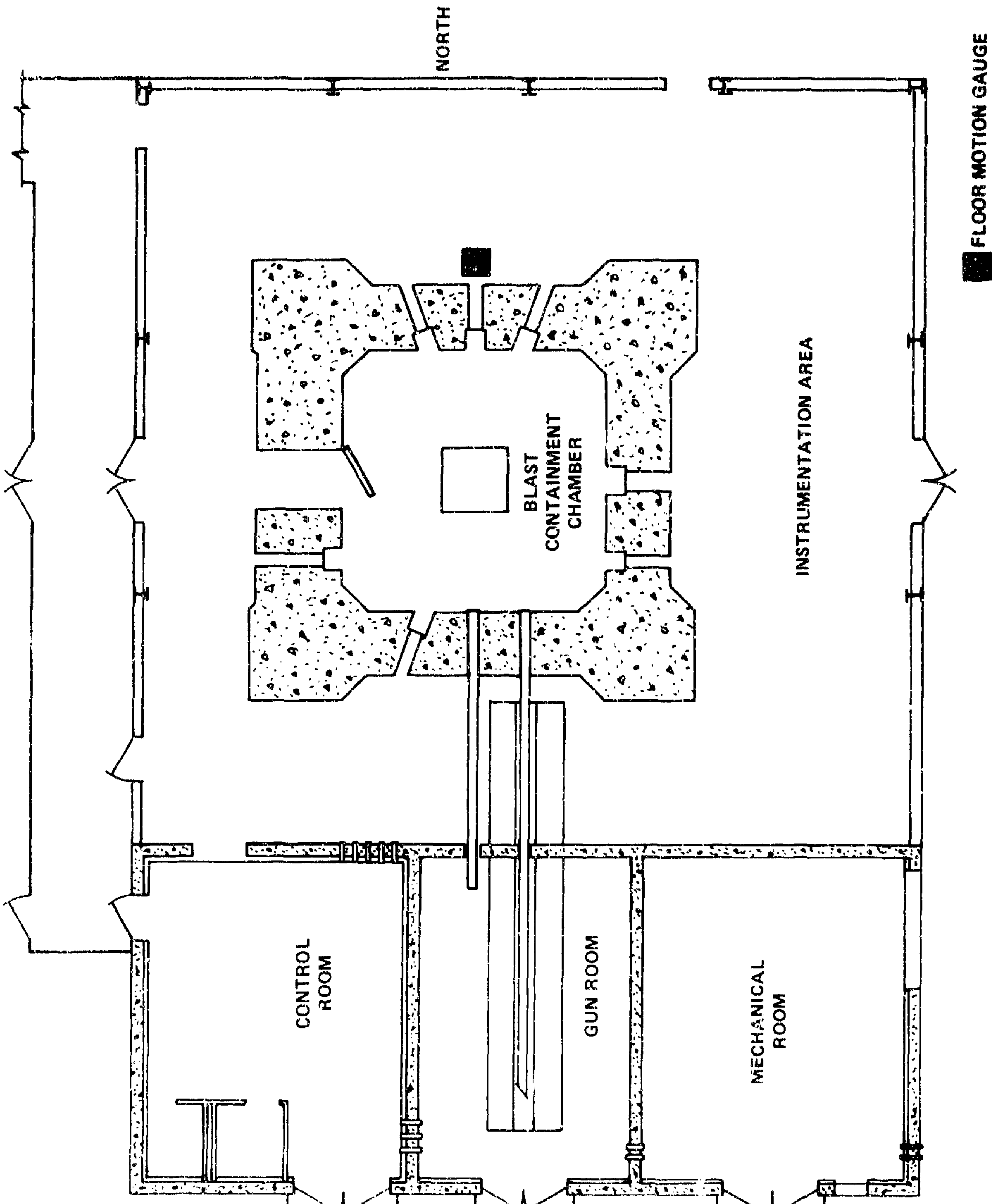


FIGURE 4-1. LOCATION OF FLOOR MOTION GAUGE

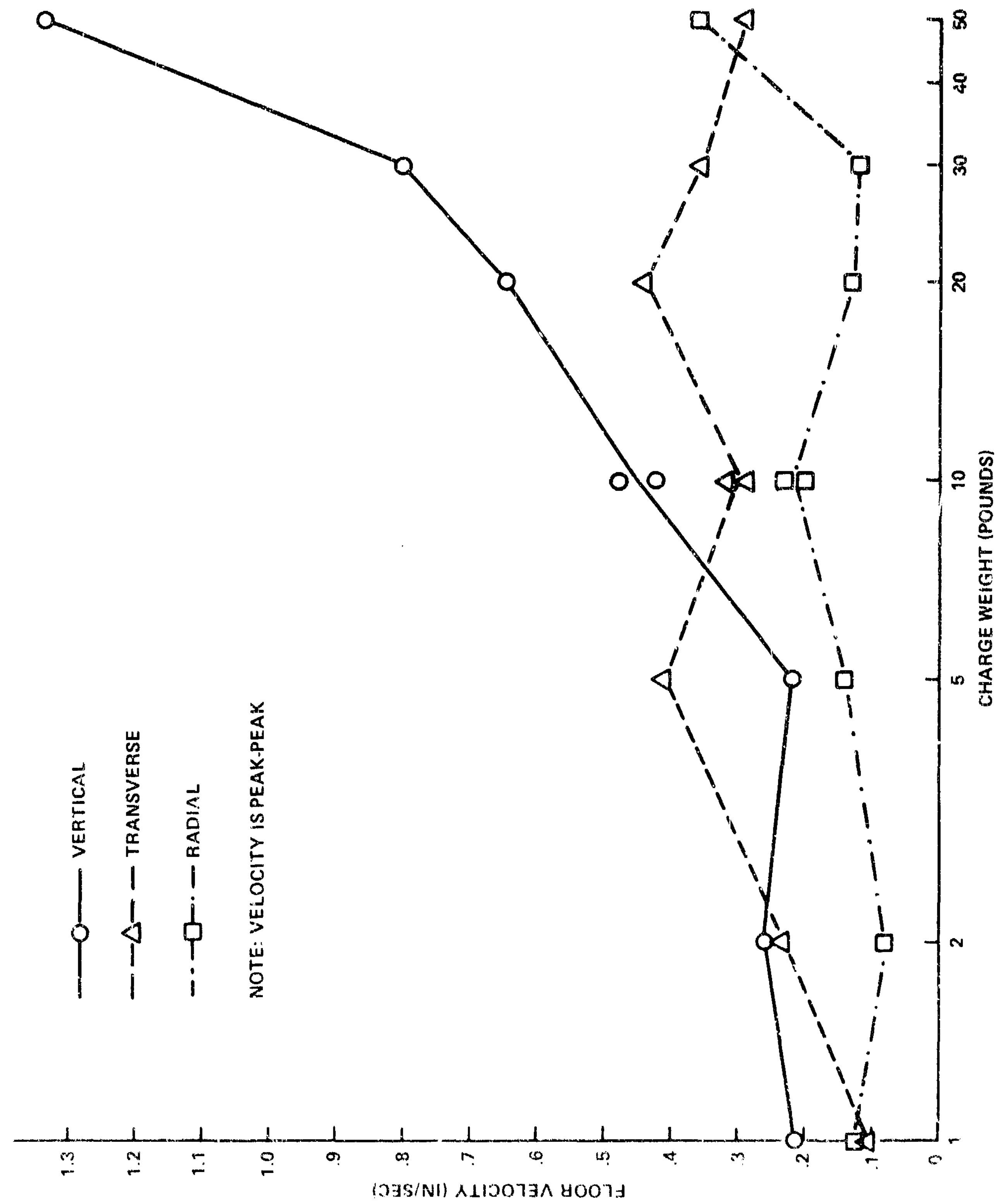


FIGURE 4-2. FLOOR VELOCITY VERSUS CHARGE WEIGHT

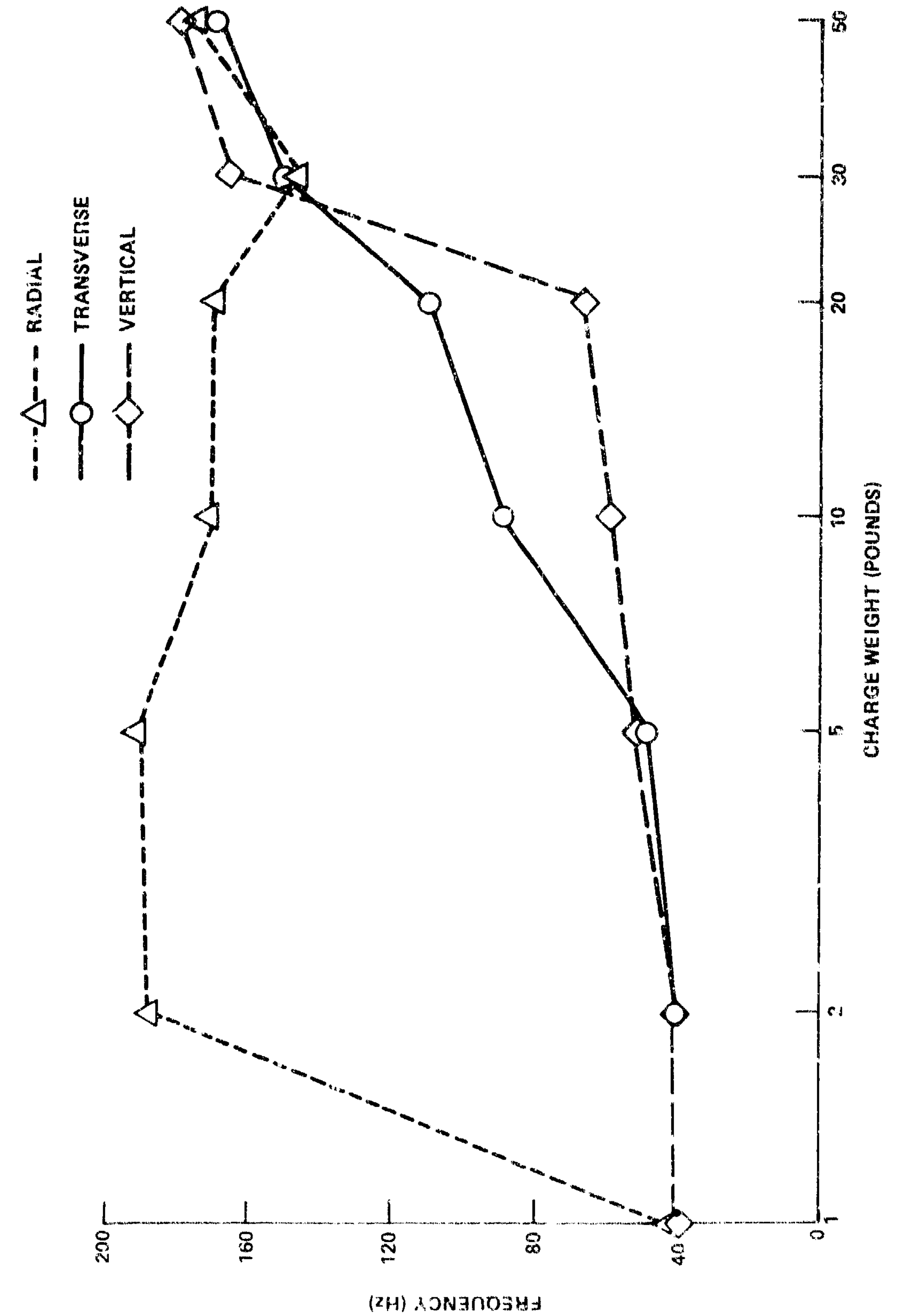


FIGURE 4-3. FLOOR MOTION FREQUENCY VERSUS CHARGE WEIGHT

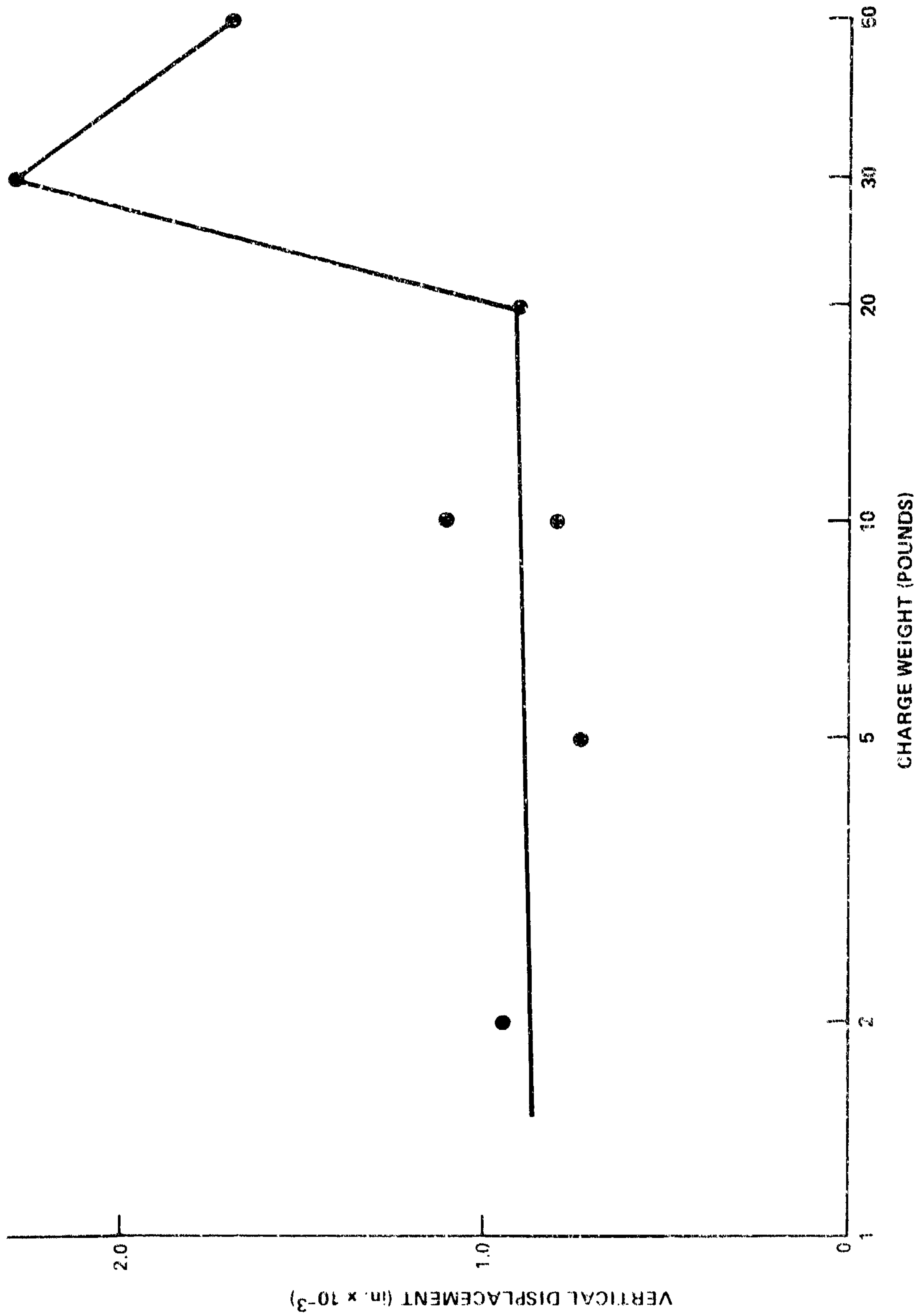


FIGURE 4.4. VERTICAL DISPLACEMENT OF FLOOR VERSUS CHARGE WEIGHT

TABLE 4-1. FLOOR MOTION DATA

EXPLOSIVE WEIGHT (lb)	MAXIMUM POSITIVE VELOCITY (in/sec)	MAXIMUM NEGATIVE VELOCITY (in/sec)	MAXIMUM DISPLACEMENT ($x10^{-3}$ inch)	MINIMUM DISPLACEMENT ($x10^{-3}$ inch)	FREQUENCY (Hz)	DURATION (sec)
TRANSVERSE						
1	-	-	-	-	-	-
1	0.03	0.07	-	-	-	-
2	0.13	0.10	0.28	0.22	40	-
5	0.20	0.21	0.40	0.34	48	2.2
10	0.17	0.15	0.32	0.30	88	2.2
10	0.12	0.17	0.28	0.32	88	2.2
20	0.27	0.17	0.9	0.6	110	2.3
30	0.15	0.21	0.4	0.7	148	2.3
50	0.14	0.15	0.4	1.1	164	1.9
VERTICAL						
1	-	-	-	-	40	-
1	0.10	0.11	-	-	40	-
2	0.12	0.14	0.9	1.1	40	-
5	0.11	0.11	0.77	0.52	48	2.2
10	0.18	0.30	1.1	0.9	59	2.2
10	0.21	0.21	0.8	0.8	57	2.2
20	0.30	0.35	0.9	1.0	65	2.3
30	0.42	0.40	2.3	2.0	162	2.3
50	0.64	0.70	1.7	1.3	168	1.7
RADIAL						
1	-	-	-	-	40	-
1	0.08	0.03	-	-	40	-
2	0.04	0.04	0.024	0.027	188	-
5	0.06	0.08	0.027	0.035	192	0.2
10	0.13	0.10	0.037	0.028	172	2.2
10	0.10	0.10	0.019	0.017	165	2.2
20	0.06	0.07	0.2	0.2	169	2.3
30	0.15	0.12	1.0	0.4	145	2.3
50	0.14	0.22	1.2	0.9	168	2.1

NOTE: Positive and Negative Velocities/Displacements are referenced to the local rest position.

CHAPTER 5

SOUND LEVEL MEASUREMENTS

Sound pressure level measurements were made at several locations both inside and outside Building 327. Measurements were made outside Building 327 at the entrance gate, parking lot, Building 348, and at Building 311. Figure 5-1 shows a map of the 300 Area and where these positions were located with respect to Building 327.

BUILDING 327

Work Area

Figure 5-2 shows the position of sound level measurements made within Building 327. The gauge positions WAN (work area north) and WAE (work area east) used a piezo-resistive pressure transducer as stated in Chapter 2. Position WA-1 was a peak-holding sound level meter, which was read manually. Position WA-2 was a condenser microphone. Table 5-1 presents the sound level measurements recorded for the nine shots fired. Appendix C shows the sound level records recorded for each test shot. Also presented is a frequency analysis for position WA-2.

For positions WAN and WAE, no pressures were detected until the 10-pound TNT charge was fired. The maximum sound pressure level measured on all the shots in the work area was 0.03 psi or 140 dB (Peak flat Sound Pressure level). This is from the 50-pound test charge. Figure 5-3 presents sound level versus explosive weight in the work area. Depending on gauge location and charge weight the sound level ranged for 102 dB (1-pound TNT) to 140 dB (50-pound TNT).

A pressure transducer was also located in the instrumentation room (control room) for all shots. For the 30- and 50-pound TNT tests pressures of 0.002 psi were measured which corresponds to 118 dB (Peak flat sound pressure level). For tests of 20 pounds or less, no sound level above background was recorded.

Outside Building 327

Table 5-1 also presents the sound pressure level measurements recorded outside Building 327. Figure 5-4 presents the sound level measurements as a function of charge weight. The ambient sound level in this part of the 300 Area

averaged 88.1 $\pm$ 2.9 dB. For charges under 10 pounds, the peak flat sound pressure level at the gate of Building 327 was less than 100 dB. Figure 5-5 presents the sound levels versus range for a 50-pound charge (worst case). The nearest point of the NSWC perimeter fence is approximately 1000 feet. At this range, the estimated peak flat sound pressure level is 97 dB (for a 50-pound charge).

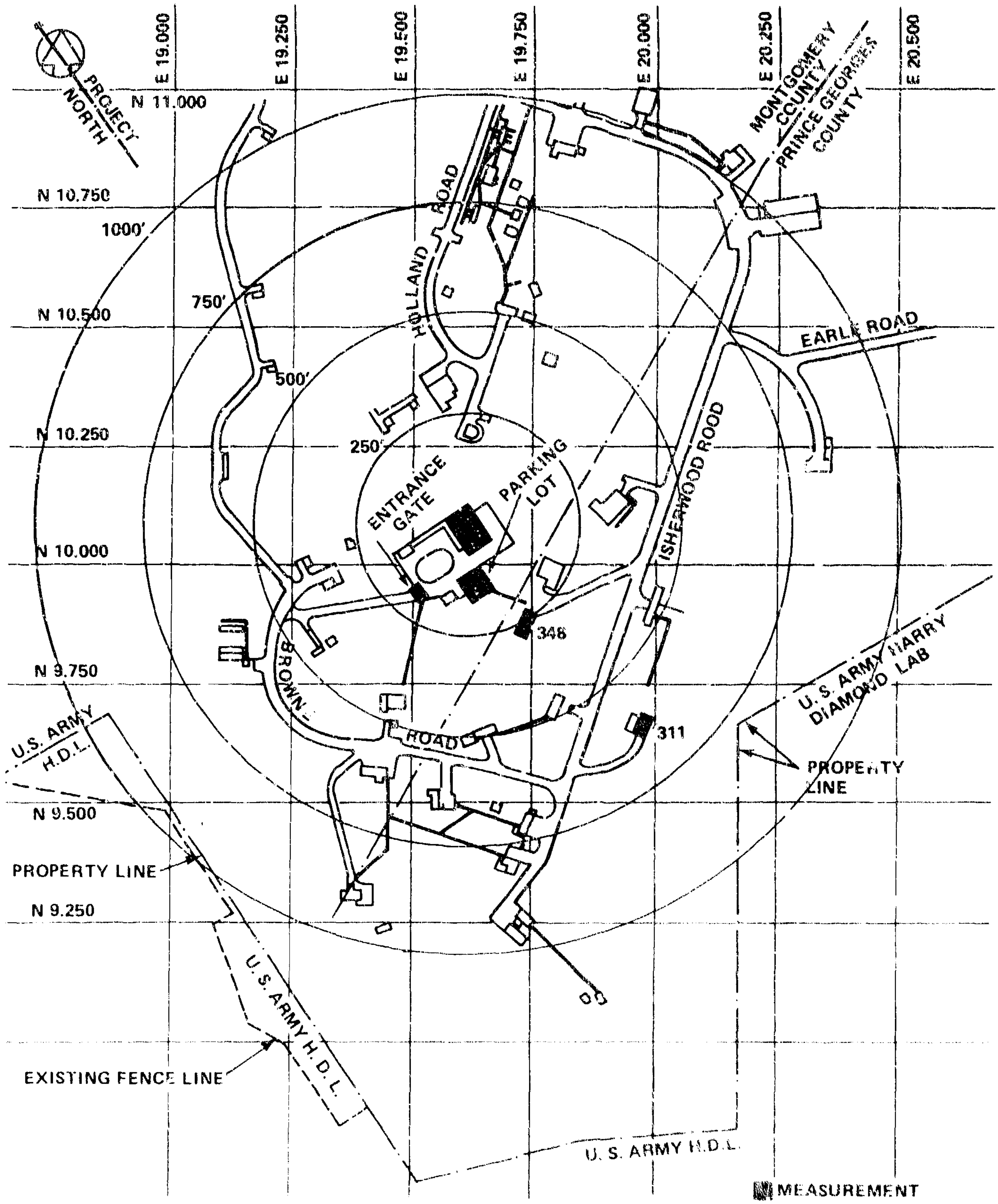


FIGURE 5-1. 300 AREA

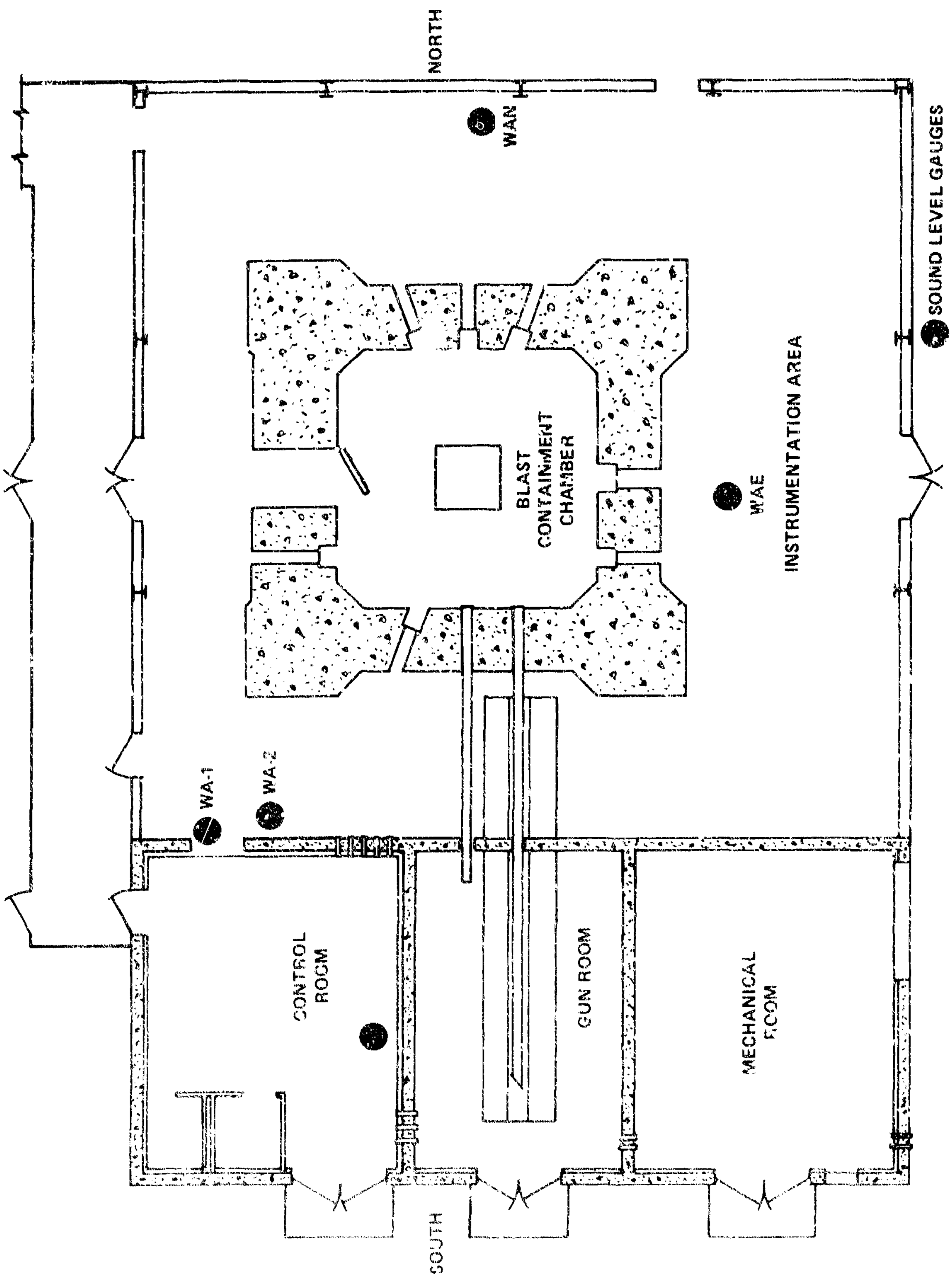


FIGURE 5-2. LOCATION OF SOUND LEVEL GAUGES

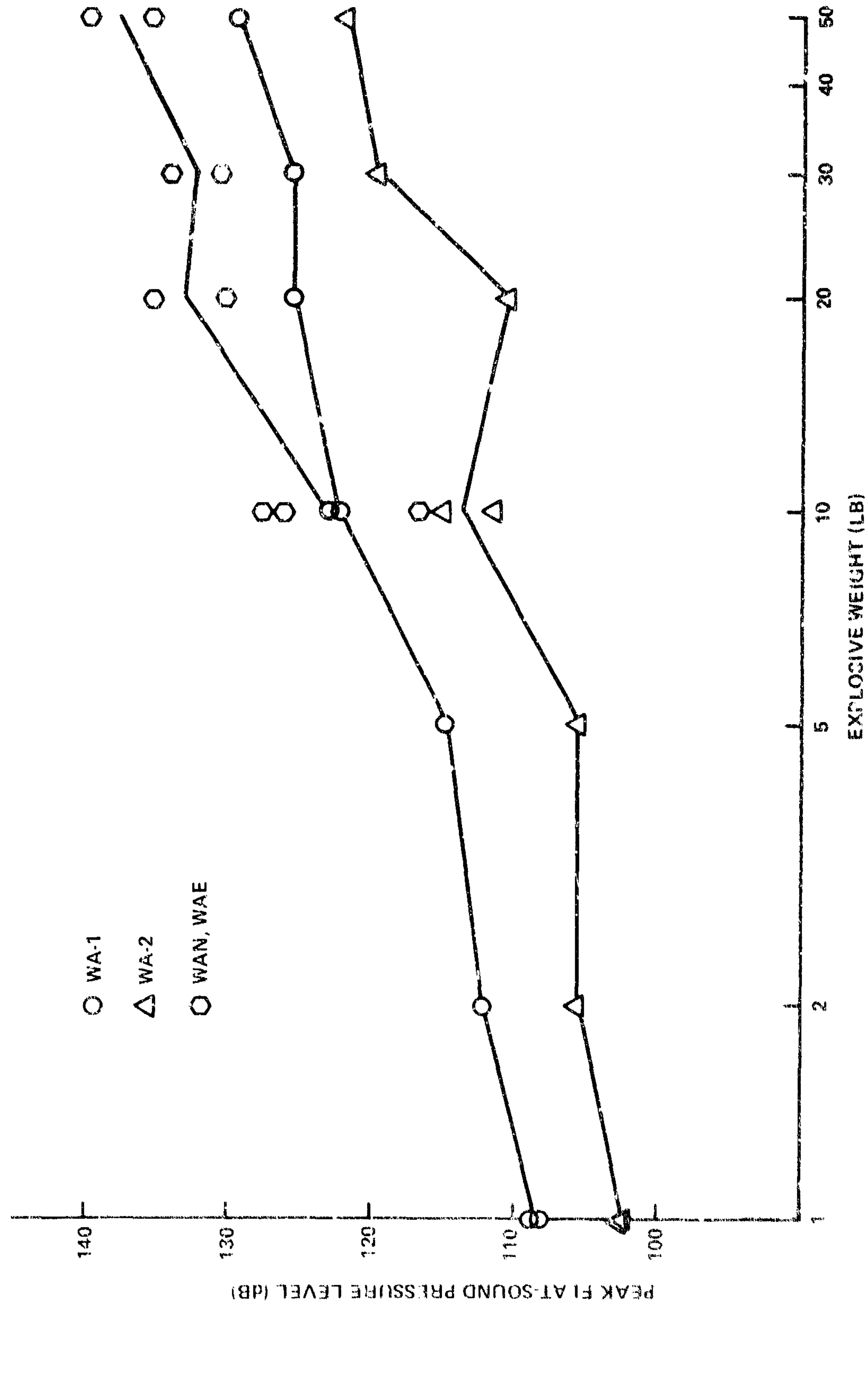


FIGURE 5-3. SOUND LEVEL VERSUS EXPLOSIVE WEIGHT IN WORK AREA AROUND BLAST CHAMBER

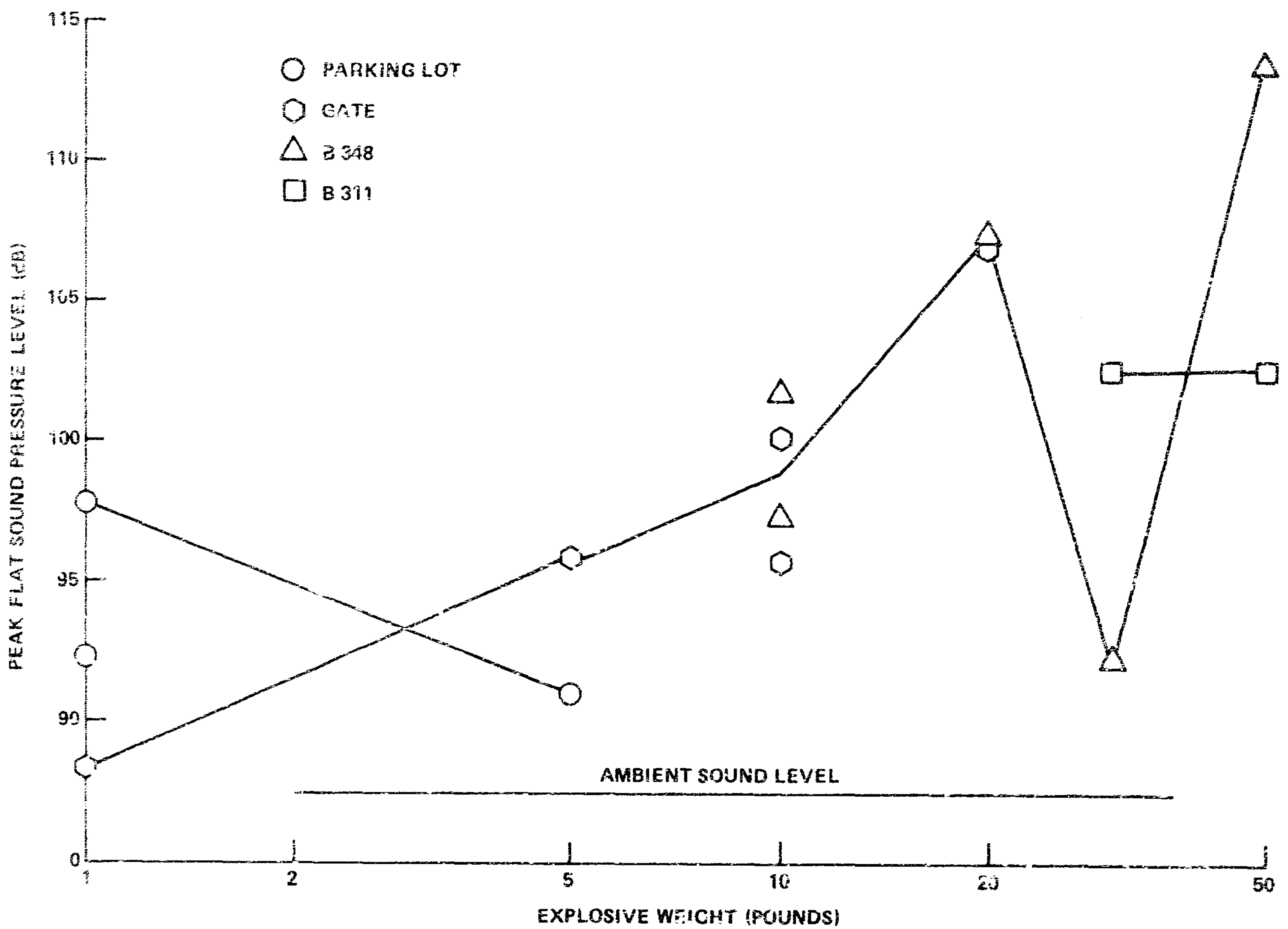


FIGURE 5-4. SOUND LEVEL VERSUS EXPLOSIVE WEIGHT OUTSIDE BUILDING 327

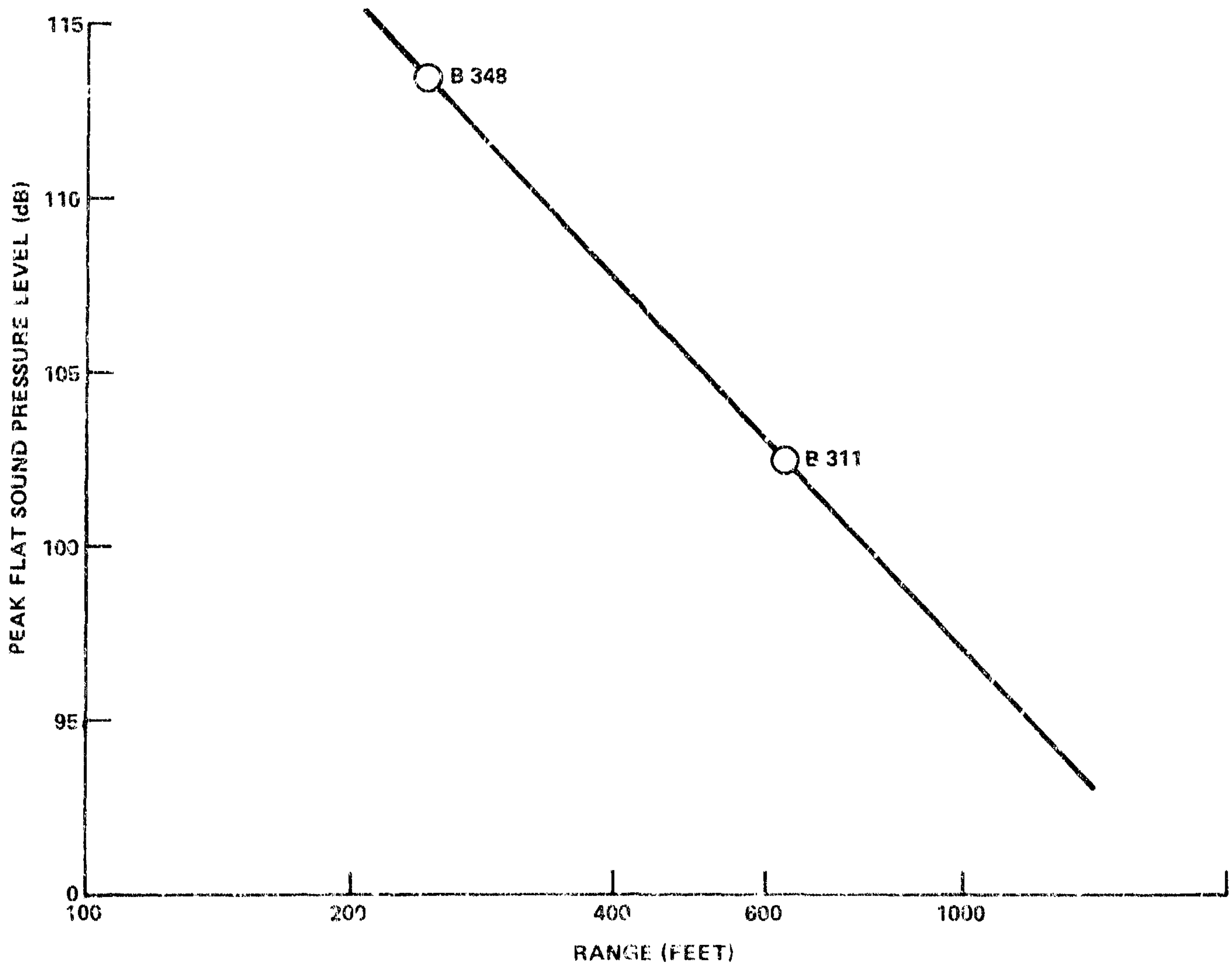


FIGURE 5-5. SOUND LEVEL VERSUS RANGE FOR 50-POUND CHARGE

TABLE 5-1. SOUND LEVEL MEASUREMENTS

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	POSITION	PEAK FLAT SOUND PRESSURE LEVEL (dB)	PRESSURE (psi)	AMBIENT SOUND LEVEL (dB)	FREQUENCY (Hz)
2302	1	PL	92.1			
		WA-1	108.2			
		WAN	-	-		
		WAE	-	-		
		WA-2	102.	0.00028		107
		CR	-			
2303	1	PL	97.8		89.9	
		GATE	88.4		89-90	
		WA-1	108.6			
		WAN	-	-		
		WAE	-	-		
		WA-2	102.	0.00025		107
		CR	-			
2304	2	PL	-	-		
		GATE	-			
		WA-1	112.			
		WAN	-	-		
		WAE	-	-		
		WA-2	105.4	0.00049		107
		CR	-			

POSITION NOTATION:

PL	Parking lot outside Building 327
GATE	Gate outside Building 327
WA-1	Work area around the blast chamber (sound level meter)
WA-2	Work area around the blast chamber (microphone)
WAN	Work area north side
WAE	Work area east side
CR	Control room
B348	Outside Building 348
B311	Outside Building 311

TABLE 5-1. SOUND LEVEL MEASUREMENTS (Cont.)

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	POSITION	PEAK FLAT SOUND PRESSURE LEVEL (dB)	PRESSURE (psi)	AMBIENT SOUND LEVEL (dB)	FREQUENCY (Hz)
2305	5	PL	91.0		89	
		GATE	95.8		87.2	
		WA-1	114.9			
		WAN	-	-		
		WAE	-	-		
		WA-2	105.5	0.0004		108
		CR	-	-		
2306	10	B348	101.6		86.6	
		GATE	100.2		90.9	
		WA-1	122.2			
		WAN	116.7	0.0020		
		WAE	-	-		
		WA-2	115.	0.0015		87
		CR	-			
2307	10	B348	97.3		86.6	
		GATE	95.8		88.7	
		WA-1	122.6			
		WAN	128.2	0.0075		
		WAE	126.2	0.0061		
		WA-2	111.5	0.0011		
		CR	-			
2308	20	B348	107.2		86.1	
		GATE	107.		89.7	
		WA-1	125.5			
		WAN	130.4	0.0095		
		WAE	135.5	0.0175		
		WA-2	110.5	0.0013		107
		CR	-			

POSITION NOTATION:

PL	Parking lot outside Building 327
GATE	Gate outside Building 327
WA-1	Work area around the blast chamber (sound level meter)
WA-2	Work area around the blast chamber (microphone)
WAN	Work area north side
WAE	Work area east side
CR	Control room
B348	Outside Building 348
B311	Outside Building 311

TABLE 5-1. SOUND LEVEL MEASUREMENTS (Cont.)

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	POSITION	PEAK FLAT SOUND PRESSURE LEVEL (dB)	PRESSURE (psi)	AMBIENT SOUND LEVEL (dB)	FREQUENCY (Hz)
2309	30	B348	92.4		80.0	
		B311	102.5		88.3	
		WA-1	125.7			
		WAN	130.9	0.010		
		WAE	134.2	0.15		
		WA-2	119.5	0.0029		107
		CR	115.0	0.00165		
2310	50	B348	113.5		87.4	
		B311	102.5		92.1	
		WA-1	129.6			
		WAN	136.6	0.020		
		WAE	140.0	0.030		
		WA-2	122.	0.038		170
		CR	117.9	0.0023		

POSITION NOTATION:

PL	Parking lot outside Building 327
GATE	Gate outside Building 327
WA-1	Work area around the blast chamber (sound level meter)
WA-2	Work area around the blast chamber (microphone)
WAN	Work area north side
WAE	Work area east side
CR	Control room
B348	Outside Building 348
B311	Outside Building 311

CHAPTER 6

BLAST CHAMBER MEASUREMENTS

The quasi-static pressure measurements made during the initial phase of the testing of Building 327 were found to be unacceptable. All of the blast gages which were used contained a reference pressure tube venting the sensor to ambient air pressure. Thus, all the quasi-static measurements vented too quickly, not allowing the full long-duration pressure to be seen.

In September 1985, additional tests were conducted to supplement the earlier environmental testing at Building 327. Eleven OCTOL (75% HMX/25% TNT) tests with explosive weights ranging between 0.64 to 1.90 pounds were fired; in addition, one 20-pound and one 44-pound TNT shot were also conducted. Pressure transducers were placed on three walls of the blast chamber to measure quasi-static pressure. Figure 6-1 shows the position of the gauges. Only five of the six positions were used on the 20- and 44-pound tests.

Table 6-1 gives the shot number and explosive weight for each test. Table 6-2 presents the quasi-static pressure recorded for each shot as well as its mean and standard deviation. Appendix D gives the pressure-time (P-t) histories for each test.

Figure 6-2 is a graph showing quasi-static pressure versus explosive weight for small (less than 2-pound) OCTOL charges. The solid curve is a prediction made using the computer code INBLAS. The equation for the pressure produced by the detonation of OCTOL explosives in the 327 blast chamber is:

$$P = 1.5701\ W^{0.9770}$$

where

P = quasi-static pressure in psi
W = explosive weight of OCTOL in pounds

The mean pressure recorded on each test is shown in comparison with the predicted curve. Since TNT was used for the two larger tests, a separate INBLAS prediction was made for this explosve. The predicted pressure curve for TNT in Bldg 327 is:

$$P = 2.9852\ W^{0.8591}$$

where

P = quasi-static pressure in psi
W = explosive weight of TNT in pounds

Figure 6-3 presents the quasi-static pressure versus explosive weight for TNT; the points are, again, the average pressures recorded for each charge size.

TEMPERATURE

In addition to monitoring the blast chamber for quasi-static pressure, several Type K thermocouples were used to record the temperature within the chamber. The following give the average temperature rise measured for each given explosive weight:

Explosive Weight (pounds)	Explosive Type	Temperature Rise (°C)
0.64	OCTOL	9.6
1.25	OCTOL	15.2
1.90	OCTOL	26.7
20.68	TNT	105.0
43.6	TNT	710

Figures 6-4 and 6-5 give typical temperature-time profiles for two explosive weights.

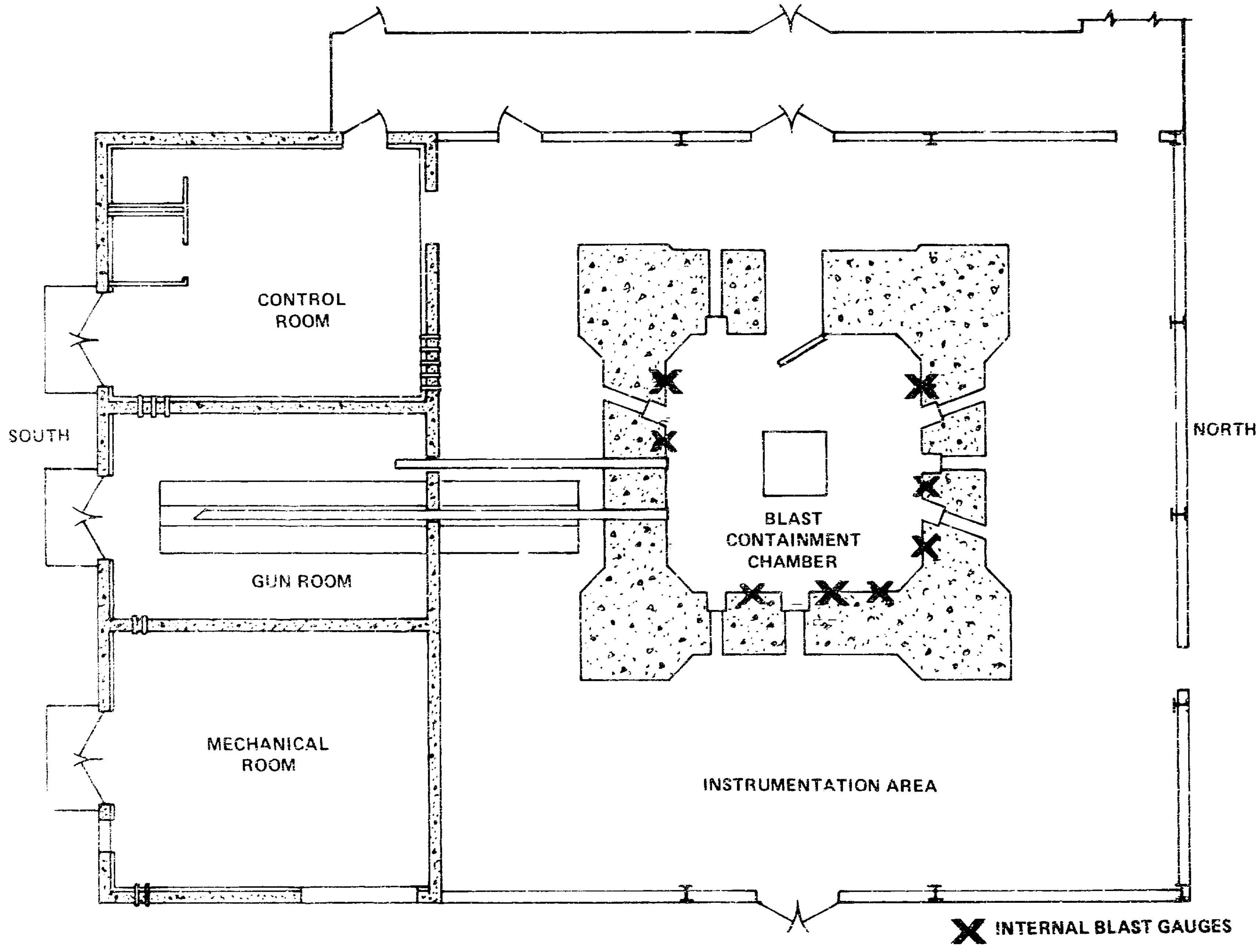


FIGURE 6-1. LOCATION OF INTERNAL PRESSURE MEASUREMENTS

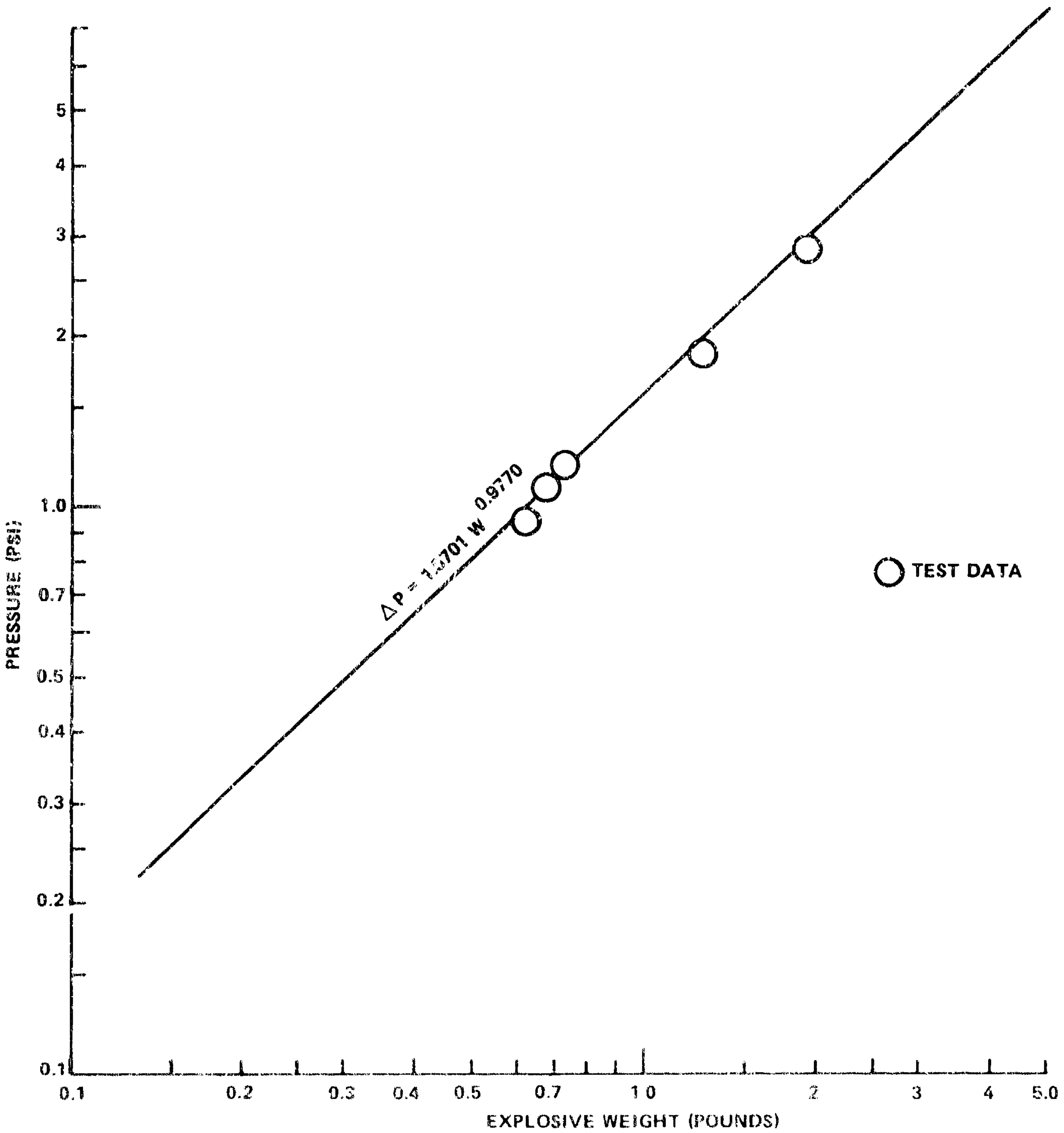


FIGURE 6-2. OCTOL QUASI-STATIC PRESSURE VERSUS EXPLOSIVE WEIGHT IN BLAST CHAMBER

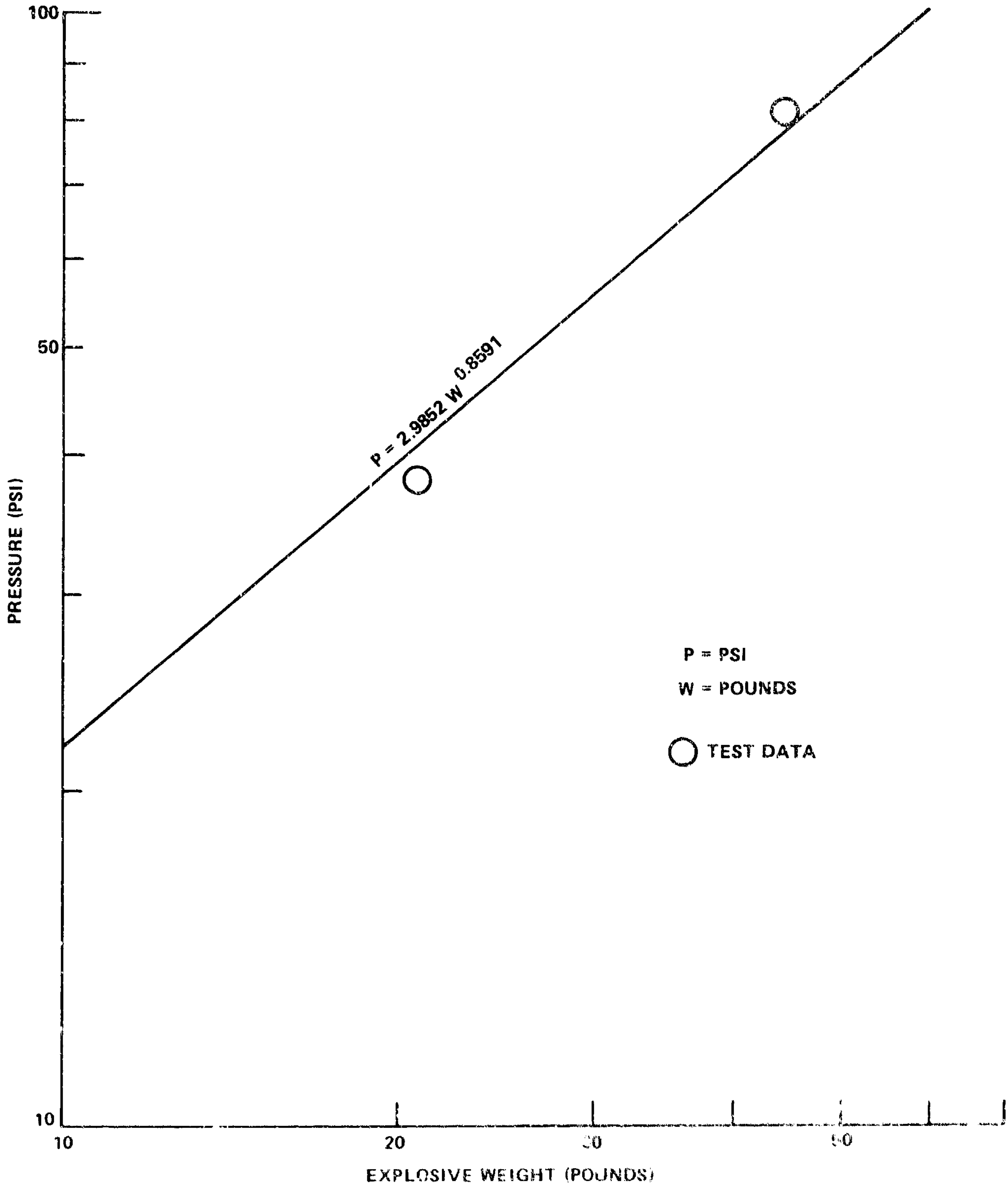
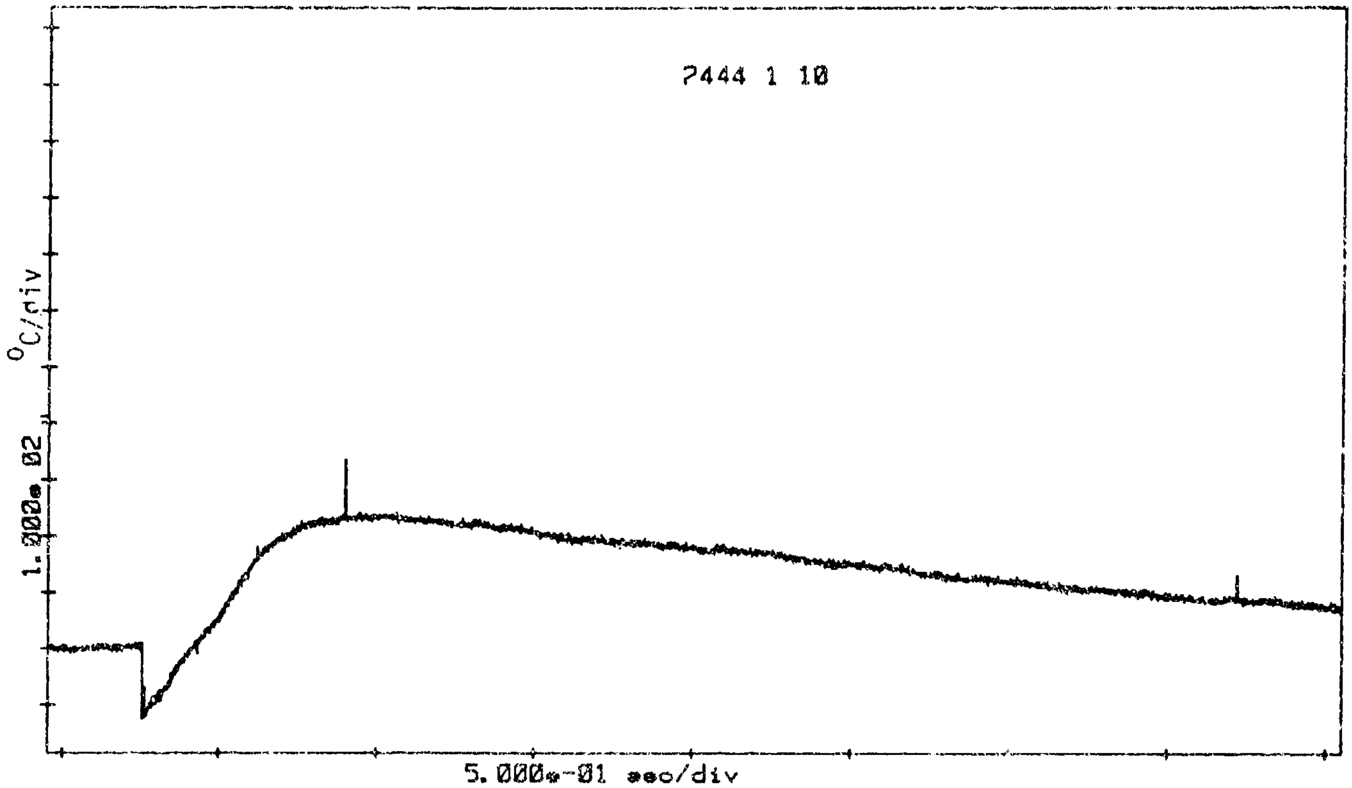


FIGURE 6-3. TNT QUASI-STATIC PRESSURE VERSUS EXPLOSIVE WEIGHT IN BLAST CHAMBER



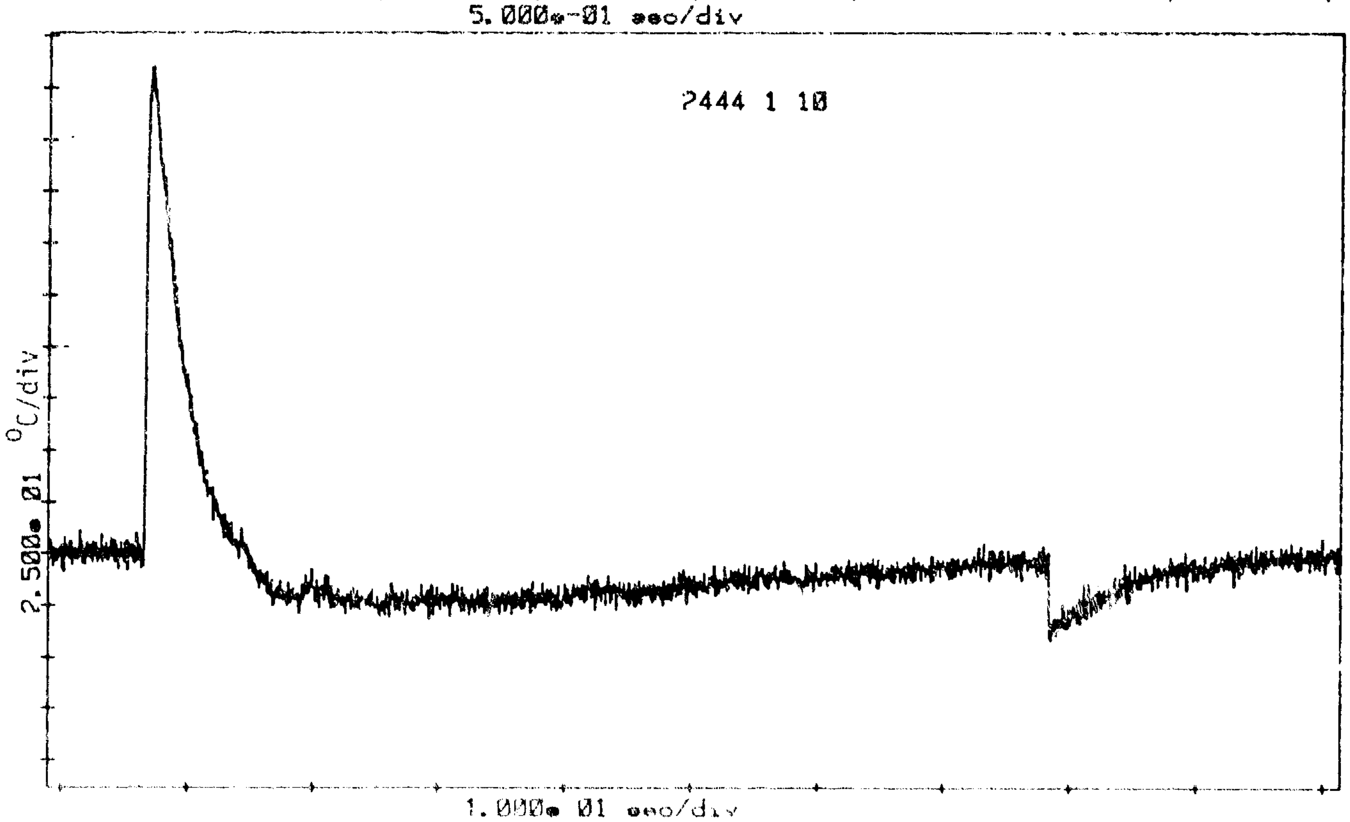


FIGURE 6-4. TEMPERATURE VERSUS TIME FOR 20-POUND CHARGE (TNT)

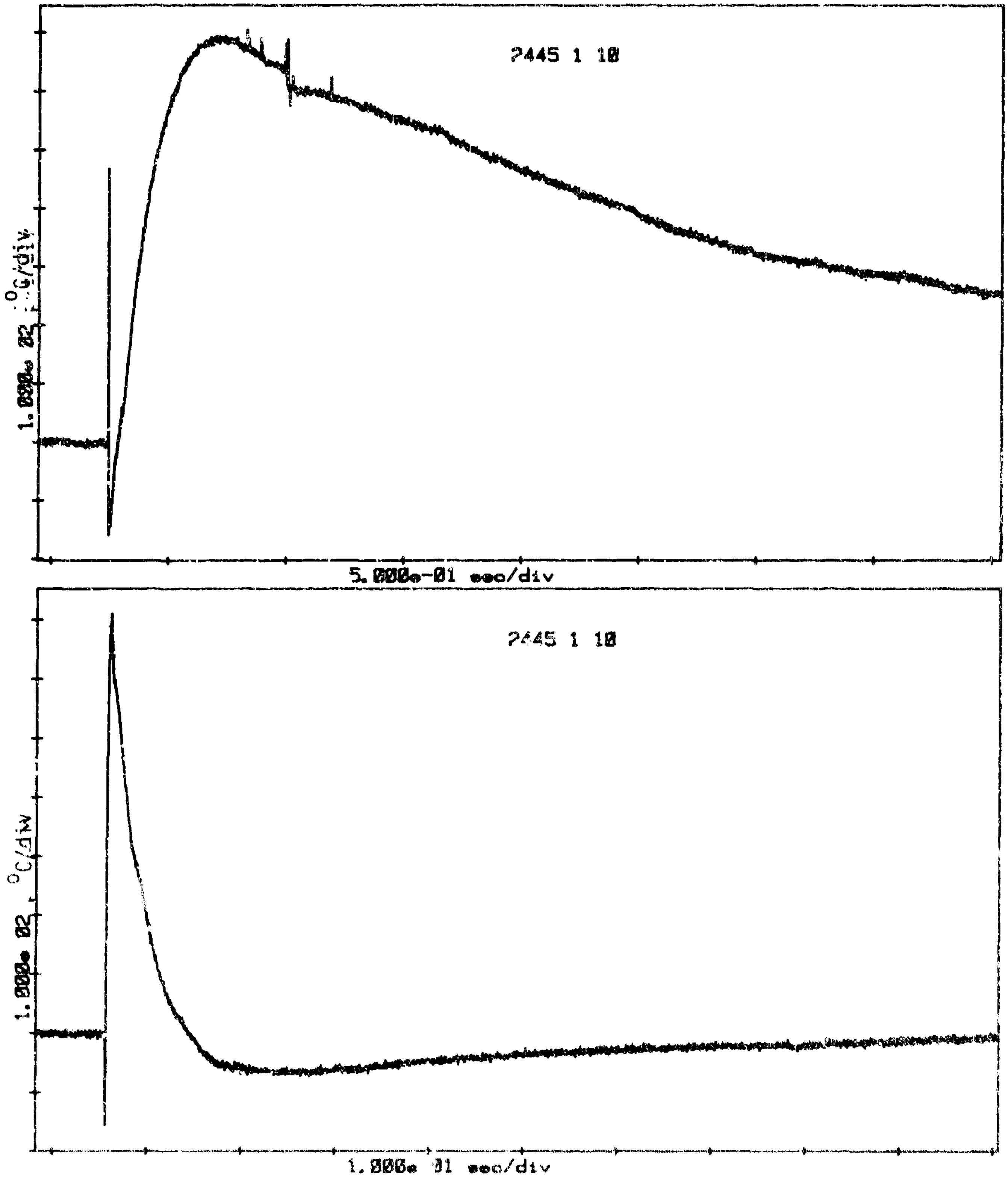


FIGURE 6-5. TEMPERATURE-TIME HISTORY FOR SHOT 2445, NOMINAL 44-POUND CHARGE

TABLE 6-1. CHARGE CONFIGURATION

SHOT NUMBER	TOTAL EXPLOSIVE WEIGHT (Lbs.)	EXPLOSIVE TYPE
2372	0.64	OCTOL
2373	0.64	OCTOL
2374	1.25	OCTOL
2375	1.90	OCTOL
2376	1.26	OCTOL
2377	1.87	OCTOL
2378	0.73	OCTOL
2379	0.75	OCTOL
2380	0.68	OCTOL
2384	0.68	OCTOL
2409	0.73	OCTOL
2444	20.68	TNT
2445	43.6	TNT

TABLE 6-2. OCTOL QUASI-STATIC PRESSURE DATA (PSI)

SHOT NUMBER	GAUGE NUMBER 1	2	3	4	5	6	7	8	MEAN	STANDARD DEVIATION
2372	0.95	0.93	0.88	0.91	0.85	0.95	0.95	1.05	0.83	0.06
2373	1.00	0.94	0.86	0.92	0.86	0.97	0.88	1.09	0.94	0.08
2374	1.91	1.65	1.59	1.76	1.72	2.14	1.67	1.78	1.78	0.18
2375	2.88	2.72	2.49	2.72	2.50	2.76	2.66	3.20	2.74	0.23
2376	1.95	1.84	1.74	1.88	1.75	1.87	1.87	2.05	1.87	0.10
2377	2.90	2.78	2.56	2.81	2.58	2.86	2.80	3.05	2.79	0.16
2378	1.42	1.28	1.39	1.32	1.24	1.32	1.29	–	1.32	0.06
2379	1.26	1.16	1.13	1.21	1.16	1.20	1.18	1.20	1.19	0.04
2380	1.10	0.98	0.91	1.04	1.00	1.06	1.02	1.05	1.02	0.06
2384	1.13	1.08	1.12	1.07	1.01	1.05	1.03	1.10	1.07	0.04
2409	1.11	1.02	0.96	1.01	0.94	1.02	1.00	0.92	1.00	0.06
2444*		38.0		35.2	37.1		37.8	37.4	37.1	1.12
2445*		82.0			79.2		82.2	–	81.1	1.68

* TEST EXPLOSIVE WAS TNT

CHAPTER 7

DOOR ACCELERATION

A single accelerometer was mounted on the outer wall of the inner steel door of the blast chamber. This is not a solid steel door; it has a steel outer plate on the back side. The gauge was mounted where it was thought the best coupling of inner and outer plates would be made. Figure 7-1 shows where the gauge was mounted relative to the blast chamber. Table 7-1 presents the data. Two measurements are given, an initial acceleration measurement and a maximum measurement that includes the ringing of the gauge. Appendix E gives the acceleration-time histories recorded from each test.

Figure 7-2 presents door acceleration versus explosive weight. The data are somewhat inconsistent but for charges less than 10 pounds the door acceleration is less than 30 g's. The only other measurement recorded was the 50-pound test where the door movement is about three times higher.

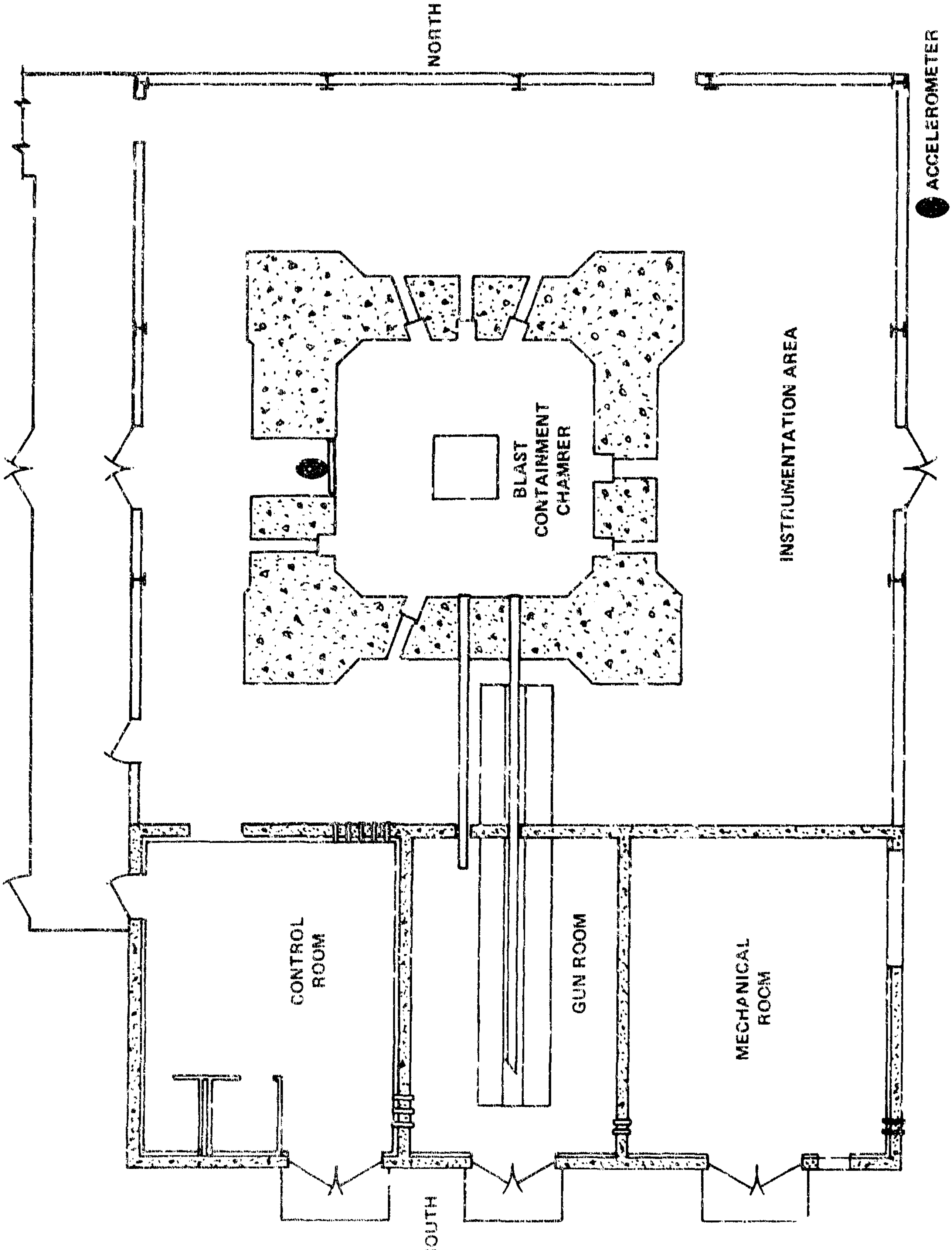


FIGURE 7-1. LOCATION OF ACCELEROMETER MEASUREMENT

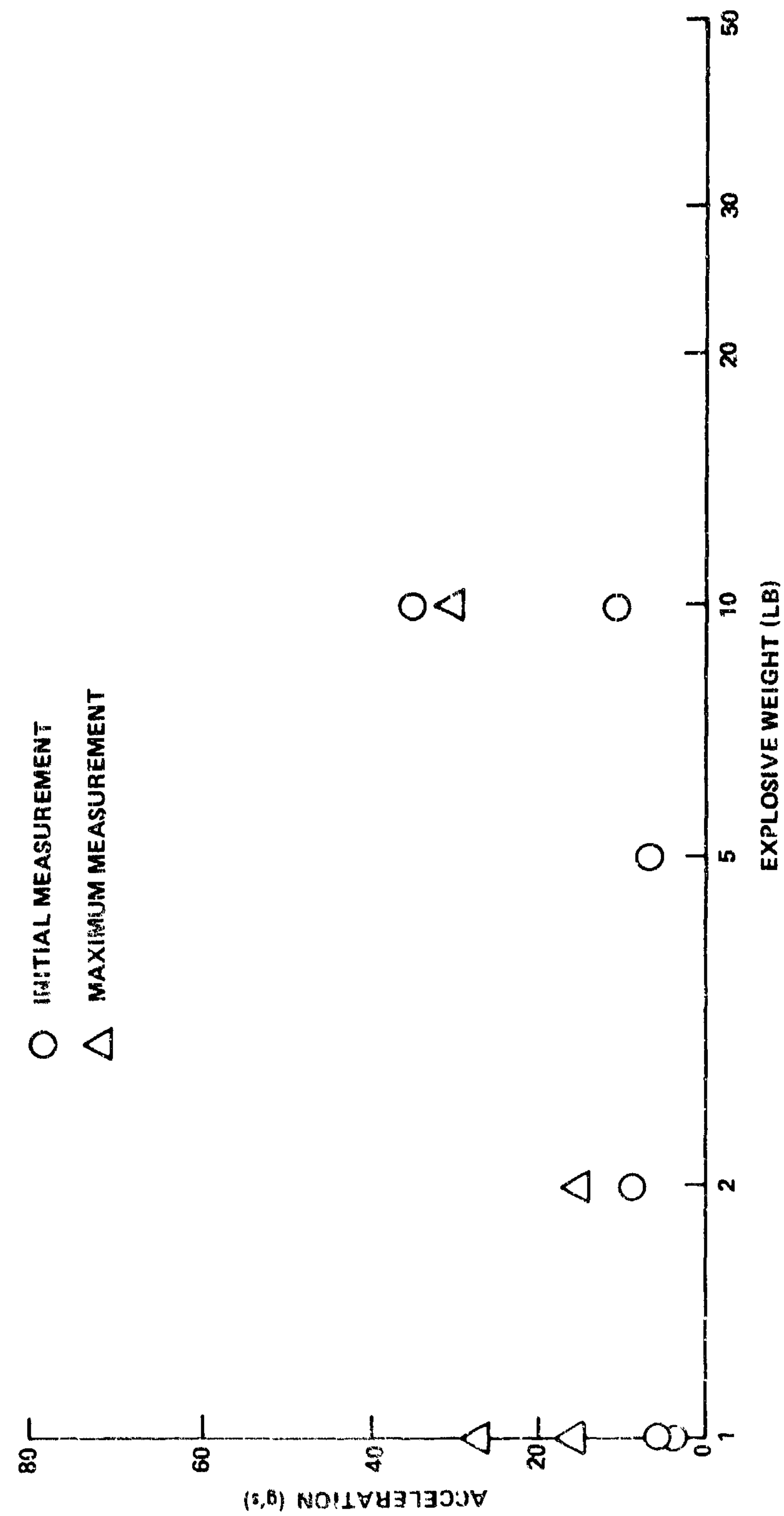


FIGURE 7-2. ACCELERATION VERSUS EXPLOSIVE WEIGHT, BLAST CHAMBER DOOR

TABLE 7-1. ACCELEROMETER GAUGE DATA

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	INITIAL MEASUREMENT (g)	MAXIMUM MEASUREMENT (g)
2302	1	6.0	27.0
2303	1	4.0	15.5
2304	2	9.0	15.0
2305	5	6.8	-
2306	10	11.0	30.0
2307	10	35.0	-
2308	20	-	-
2309	30	-	-
2310	50	80.0	350.0

POSITIONAL NOTE: Gauge was mounted on the back side of the inner blast chamber door.

CHAPTER 8

CARBON MONOXIDE LEVELS

Two carbon monoxide (CO) gas concentration monitors were used to determine the CO level inside the control room and the work area (see Figure 8-1). The monitors where placed in the work room in front of the door to the blast chamber and in the control room by the cable ports. The CO monitors were calibrated at the beginning of each day with a standard mixture of air containing 50 ppm of CO.

Monitored CO levels inside the control room did not exceed 10 ppm during the nine shots (see Table 8-1).

For the first five shots the CO levels inside the work room were negligible. For the second 10-pound shot and the 20-pound shot, the CO levels were 10 ppm and 20 ppm, respectively (see Figure 8-2). The CO monitor was turned on late for the 30-pound shot. The CO monitor was reading 50 ppm when it was turned on and the value was decreasing. The CO level then started to increase and peaked at a CO level of 55 ppm. Because the CO monitor was turned on late, the actual peak value for the CO level is not known, but must be greater than 55 ppm.

The ninth shot was the 50-pound explosive weight test. Shortly after the detonation of 50 pounds of TNT, the CO monitors went off the scale. The maximum deflection that the visicorder could handle was 130 ppm. Using a hand-held CO monitor, CO levels of 180 ppm were read inside the work room approximately 2 minutes after the detonation. The detonation set off fire alarms which resulted in the exhaust fans for the blast chamber not being turned on for approximately 1 hour. Shortly after the exhaust fans were turned on, the CO levels in the work room went down to a level of 30 ppm.

The CO levels inside the blast chamber was negligible after the venting was completed for all nine shots.

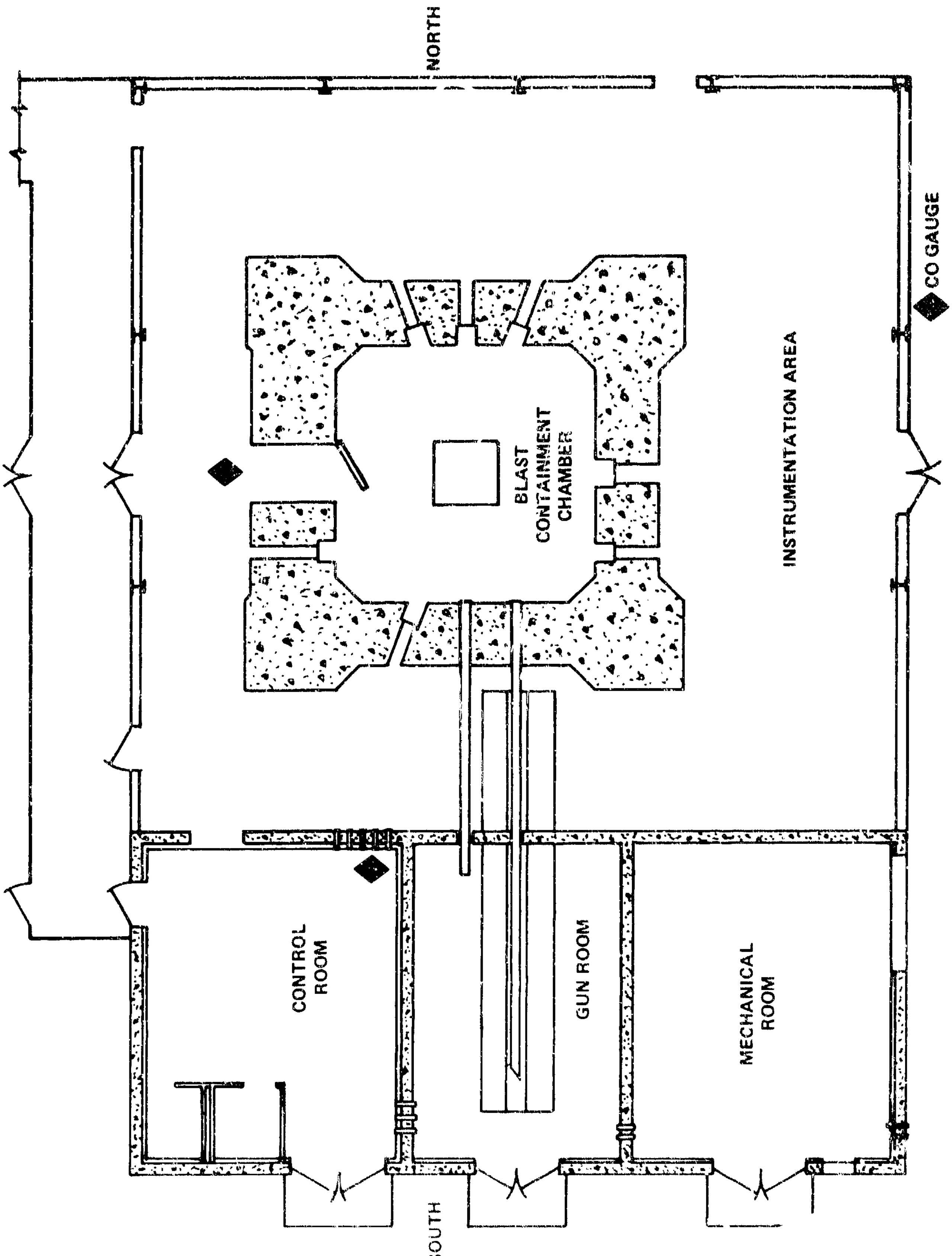


FIGURE 8-1. LOCATION OF CO CONCENTRATION MEASUREMENTS

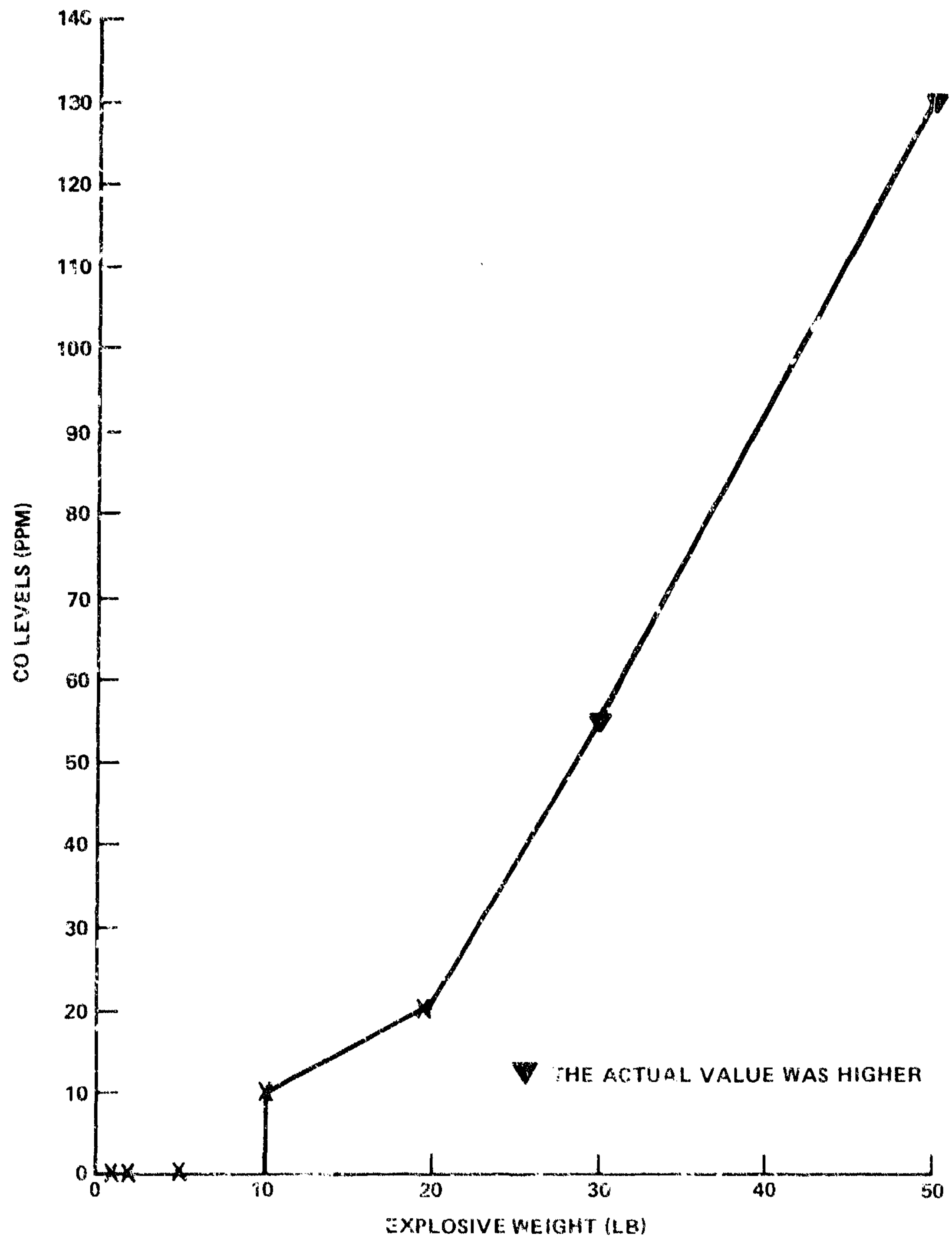


FIGURE 8-2. CO LEVELS RECORDED IN WORK ROOM

TABLE 8-1. CO LEVELS PER SHOT

SHOT NUMBER	TNT CHARGE WEIGHT (lbs)	CO LEVELS IN PARTS PER MILLION (PPM) CONTROL ROOM	WORK ROOM
1	1.0	0	0
2	1.0	0	0
3	2.0	0	0
4	5.0	0	0
5	10.0	0	0
6	10.0	0	10
7	20.0	10	20
8	30.0*	0	55+
9	50.0**	0	130+

* The visicorder was not turned on until approximately 1 minute after the shot; therefore, the CO reading was probably higher than 55 ppm.

** The visicorder went off the scale; therefore, the actual value is unknown. A reading of 130 ppm represents full-scale deflection on the visicorder.

CHAPTER 9

STRAIN MEASUREMENTS

Wall strain measurements were made at four locations (see Figure 9-1). Each position used two gauges, measuring vertical and horizontal strain. The gauges were mounted by a representative of Measurement, Inc. A total of eight gauges were used. Two gauges were mounted on the inner wall of the steel door and were thermally protected. The other six gauges were mounted on the north, east, and south outer blast chamber walls. A hole was cut through the outer steel wall and the gauges were mounted directly on the concrete (see Figure 2-3).

Table 9-1 presents the strain gauge data giving the maximum and minimum strain in units of micro in/in. Appendix F gives the strain-time histories for each gauge. The large spike at the start of the strain measurement is thought to be the direct shock passing through the wall and stimulating the strain gauge.

Figure 9-2 presents the strain versus explosive weight for the north wall. Strain in the horizontal direction was greater than the strain in the vertical direction. This is probably due to the fact that the gauges were mounted on a rib of the concrete wall and not on a full flat surface. Figure 9-3 presents strain versus explosive weight on the south wall. Strain in the horizontal and vertical directions are similar. Figure 9-4 presents strain versus explosive weight on the east wall. These results are similar to the results found from the north wall.

Measurements were made on the door for the first three shots (1 and 2 pound charges). On the 5 pound test, the gauges failed because of a combination of both heat and reflected pressures. No further measurements were made on the door.

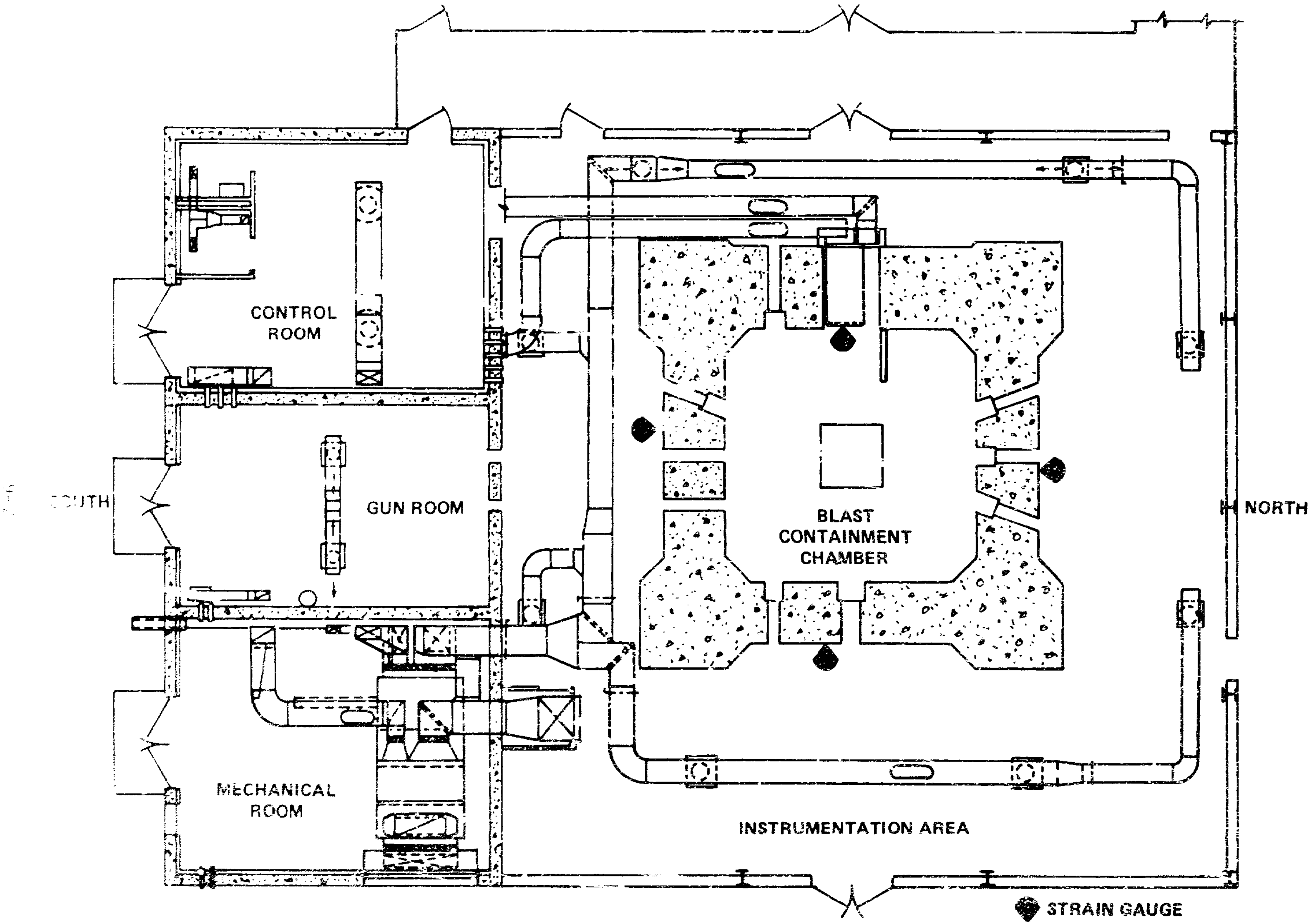


FIGURE 9-1. LOCATION OF STRAIN GAUGES

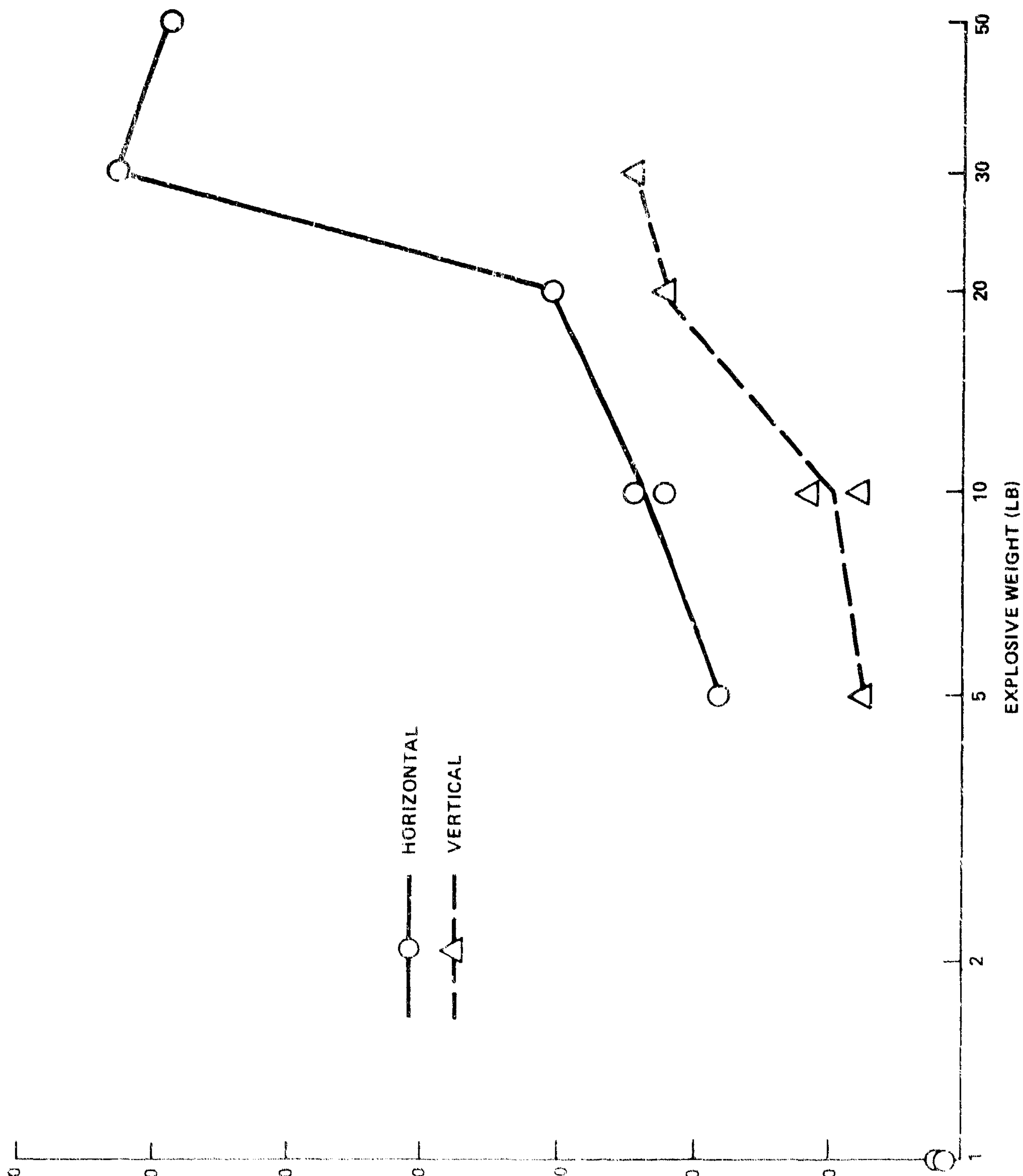


FIGURE 9-2. STRAIN VERSUS EXPLOSIVE WEIGHT, NORTH WALL

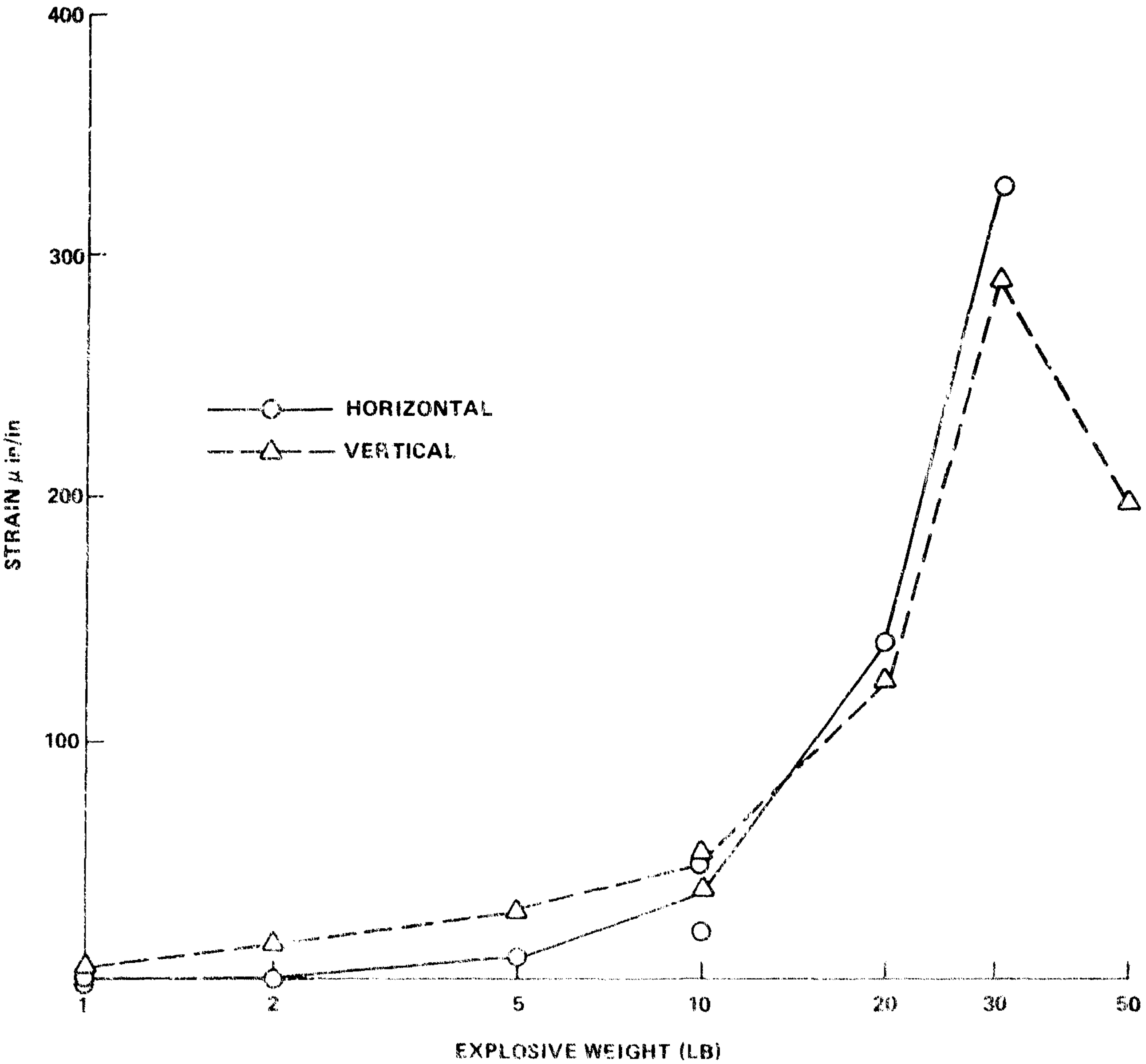


FIGURE 9-5. STRAIN VERSUS EXPLOSIVE WEIGHT, SOUTH WALL

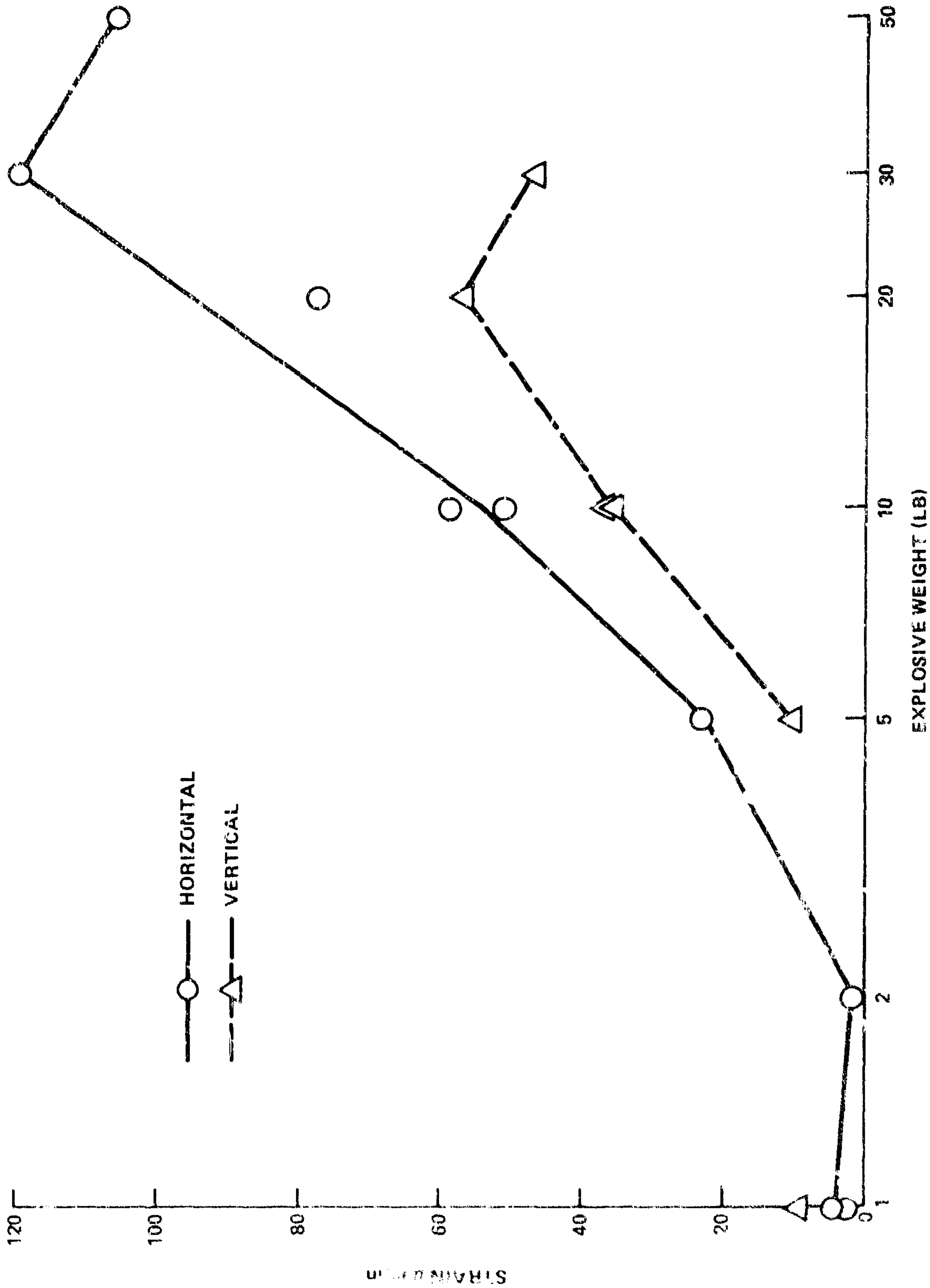


FIGURE 9-4. STRAIN VERSUS EXPLOSIVE WEIGHT, EAST WALL

TABLE 9-1. STRAIN GAUGE DATA

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	POSITION	MAXIMUM* STRAIN (micro in/in)	MINIMUM** STRAIN (micro in/in)
2302	1	NV	-	-
		NH	3.2	1.03
		EV	9.3	5.5
		EH	4.1	1.7
		SV	1.8	8.6
		SH	2.2	2.0
		DV	190.0	141.0
		DH	169.0	320.0
2304	1	NV	-	-
		NH	2.9	3.0
		EV	-	-
		EH	2.2	2.3
		SV	-	-
		SH	2.3	2.7
		DV	353.0	351.0
		DH	278.0	369.0
2305	2	NV	-	-
		NH	-	-
		EV	-	-
		EH	1.9	2.3
		SV	16.0	2.4
		SH	2.0	3.3
		DV	598.0	351.0
		DH	1619.0	1733.0

POSITION NOTATION:
NV--North wall vertical gauge
NH--North wall horizontal gauge
EV--East wall vertical gauge
EH--East wall horizontal gauge
SV--South wall vertical gauge
SH--South wall horizontal gauge
DV--Door vertical gauge
DH--Door horizontal gauge

* above zero
** below zero

TABLE 9-1. STRAIN GAUGE DATA (Cont.)

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	POSITION	MAXIMUM* STRAIN (micro in/in)	MINIMUM** STRAIN (micro in/in)
2305	5	NV	14.4	8.3
		NH	36.4	9.6
		EV	10.0	10.0
		EH	22.9	5.1
		SV	29.0	10.8
		SH	10.0	-
		DV	-	-
		DH	-	-
2306	10	NV	15.7	5.8
		NH	42.4	11.2
		EV	37.5	13.4
		EH	58.6	11.9
		SV	52.0	27.2
		SH	19.7	3.8
2307	10	NV	23.0	24.0
		NH	49.1	14.1
		EV	35.9	37.8
		EH	50.8	8.3
		SV	36.6	31.3
		SH	49.5	3.6
2308	20	NV	44.0	95.9
		NH	60.9	5.5
		EV	56.3	57.8
		EH	50.8	8.3
		SV	124.0	26.0
		SH	139.0	245.0

POSITION NOTATION:
NV--North wall vertical gauge
NH--North wall horizontal gauge
EV--East wall vertical gauge
EH--East wall horizontal gauge
SV--South wall vertical gauge
SH--South wall horizontal gauge
DV--Door vertical gauge
DH--Door horizontal gauge

* above zero
** below zero

TABLE 9-1. STRAIN GAUGE DATA (Cont.)

SHOT NUMBER	EXPLOSIVE WEIGHT (lb)	POSITION	MAXIMUM* STRAIN (micro in/in)	MINIMUM** STRAIN (micro in/in)
2309	30	NV	49.3	16.9
		NH	125.0	13.4
		EV	46.4	17.2
		EH	120.0	42.7
		SV	287.0	105.0
		SH	343.0	-
2310	50	NV	-	-
		NH	117.0	21.2
		EV	-	-
		EH	106.0	27.5
		SV	200.0	200.0
		SH	-	-

POSITION NOTATION: NV--North wall vertical gauge
NH--North wall horizontal gauge
EV--East wall vertical gauge
EH--East wall horizontal gauge
SV--South wall vertical gauge
SH--South wall horizontal gauge
DV--Door vertical gauge
DH--Door horizontal gauge

* above zero
** below zero

CHAPTER 10

SUMMARY

Before the start of this study, several people expressed their concern that the Blast Chamber might not be able to contain repeated 50-pound detonations. They even urged that the 50-pound test not be part of the validation program. These tests have shown that the facility is, apparently, well-designed and can take repeated 50-pound detonations. All of the measured structural parameters were well within their expected values. After the facility has been in service for several years, it is recommended that this entire series of test be repeated. This will help to determine how well the building is aging.

It was found that charges of 30 pounds or greater produced hazardous concentrations of carbon monoxide in the work area around the blast chamber. No such levels were recorded within the control room. It was also observed that for charges of 30 pounds or greater, the fire/smoke alarms were triggered when the charge was detonated. It is therefore recommended that a carbon monoxide gas detector be installed in the work area to indicate if hazardous levels of gases are present.

Sound pressure levels outside the facility were found to be in the acceptable range for all charge sizes (up to a maximum of 50 pounds). At a range of 1000 feet, the approximate range of the NSWC perimeter fence, the expected pressure from a 50-pound detonation was 97 dB peak flat sound pressure level. Within the control room of Bldg 327, the sound pressure level never exceeded 115 dB peak flat sound pressure level. In the work/instrumentation area the sound pressure levels were in the hazardous range, peaking at 135 dB peak flat sound pressure level.

Measurements made on the walls and floor of the blast chamber and on the floor of the work area indicate that the motions of these structural elements is acceptable. For certain delicate equipment being mounted in the work area, it should be noted that the floor motion appears to have a resonant frequency of between 40 and 80 Hz, depending on the charge size.

APPENDIX A

DISPLACEMENT-TIME HISTORIES

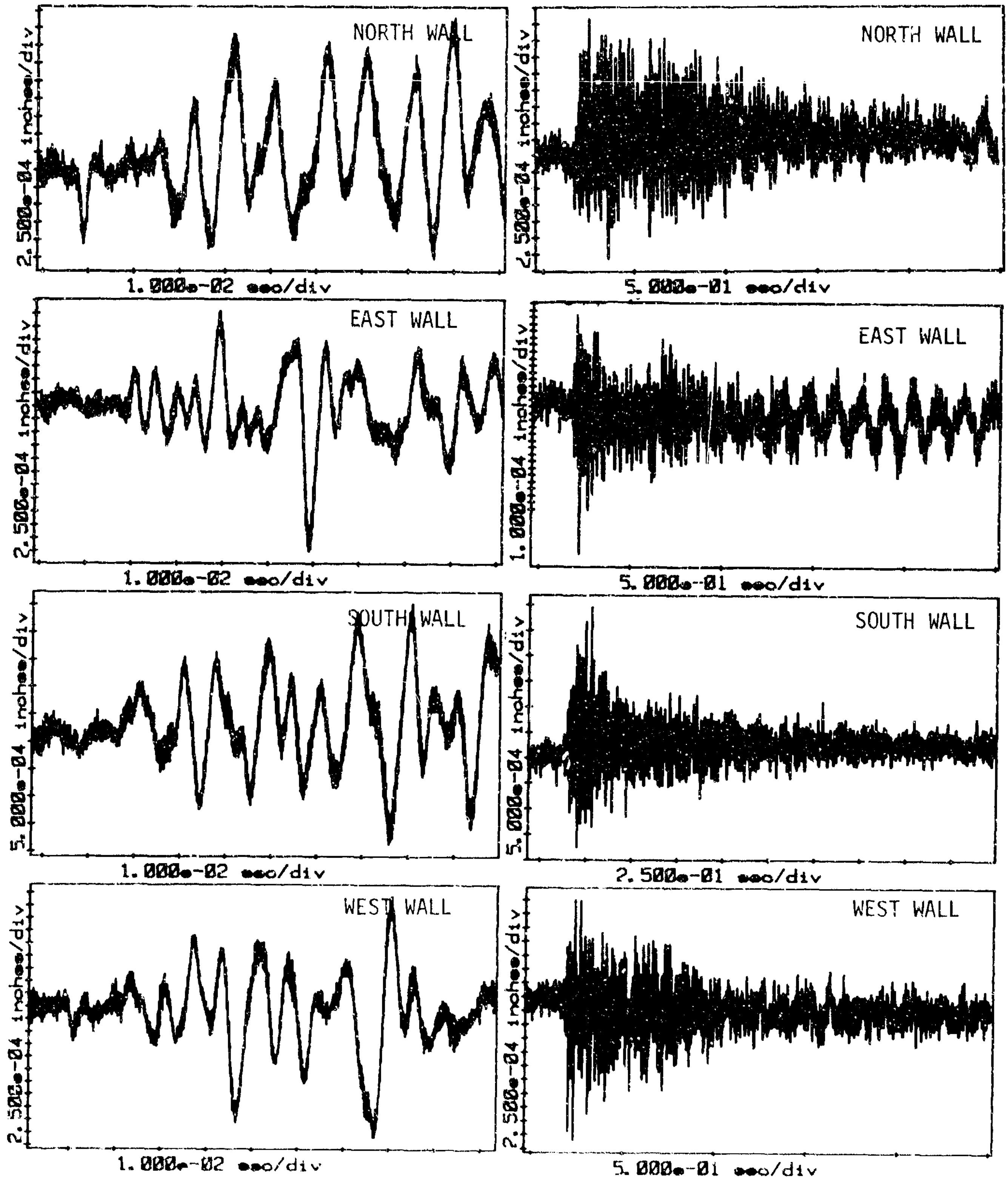


FIGURE A-1. DISPLACEMENT-TIME HISTORIES FOR SHOT 2302

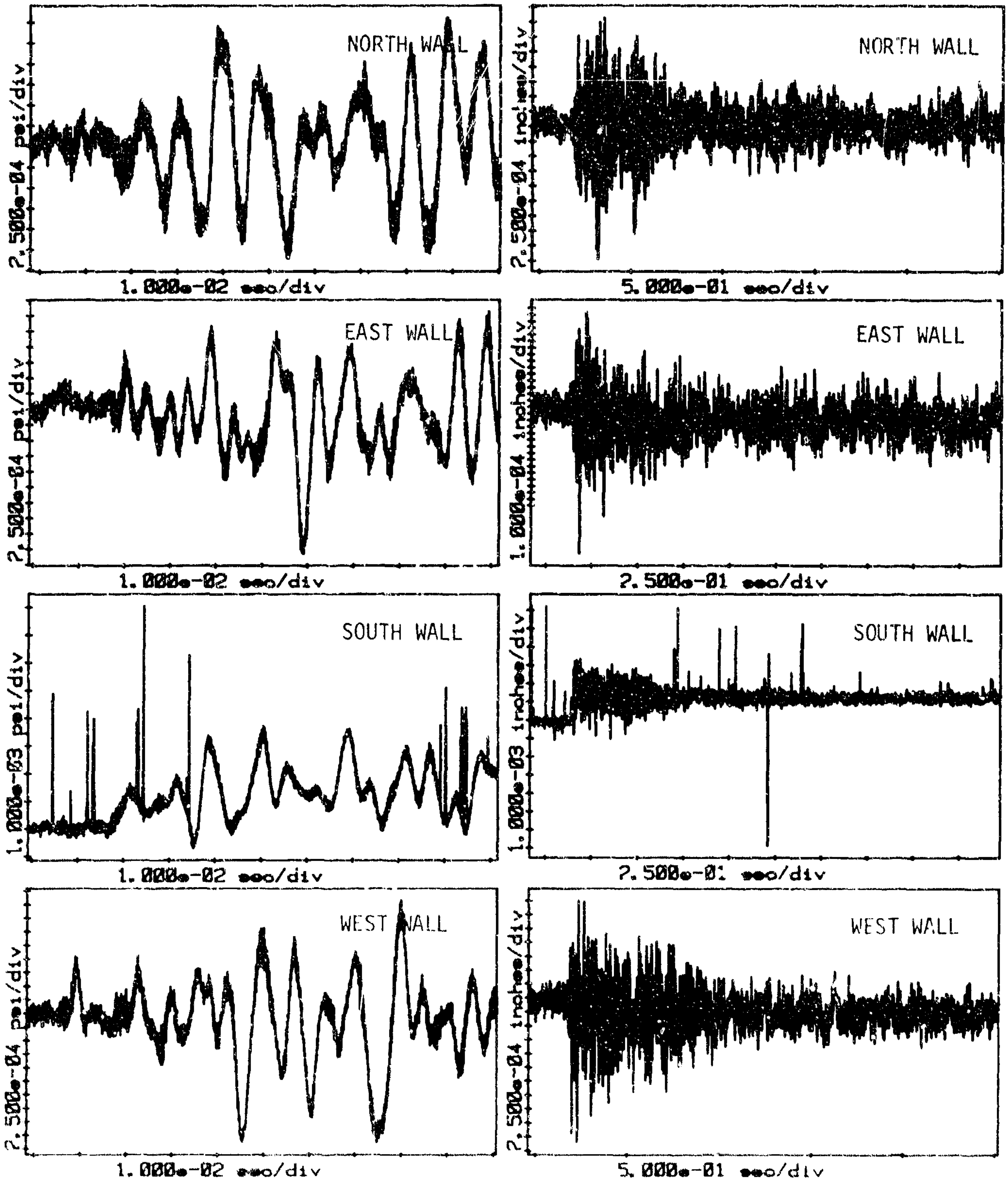


FIGURE A-2. DISPLACEMENT-TIME HISTORIES FOR SHOT 2303

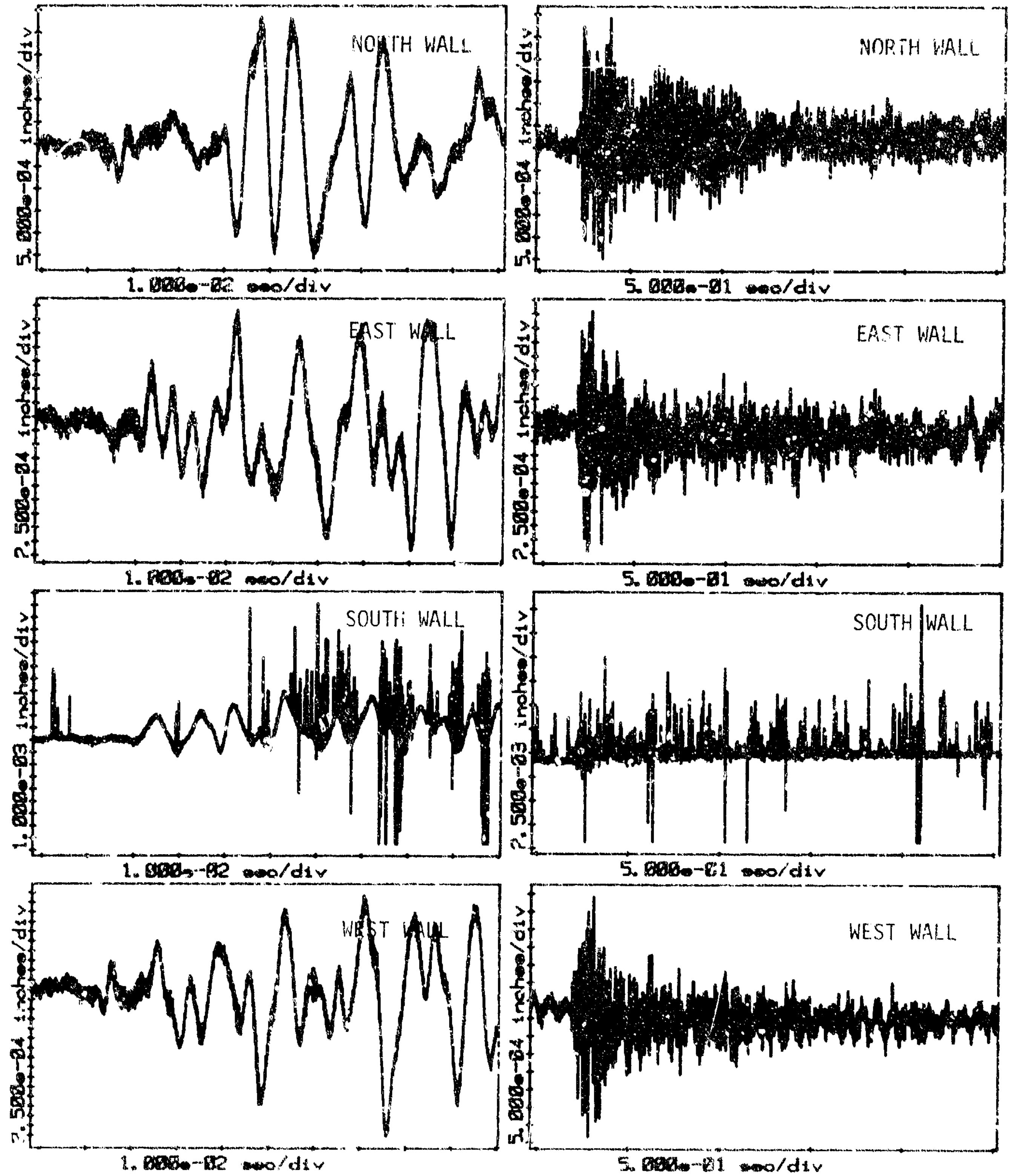


FIGURE A-3. DISPLACEMENT-TIME HISTORIES FOR SHOT 2304

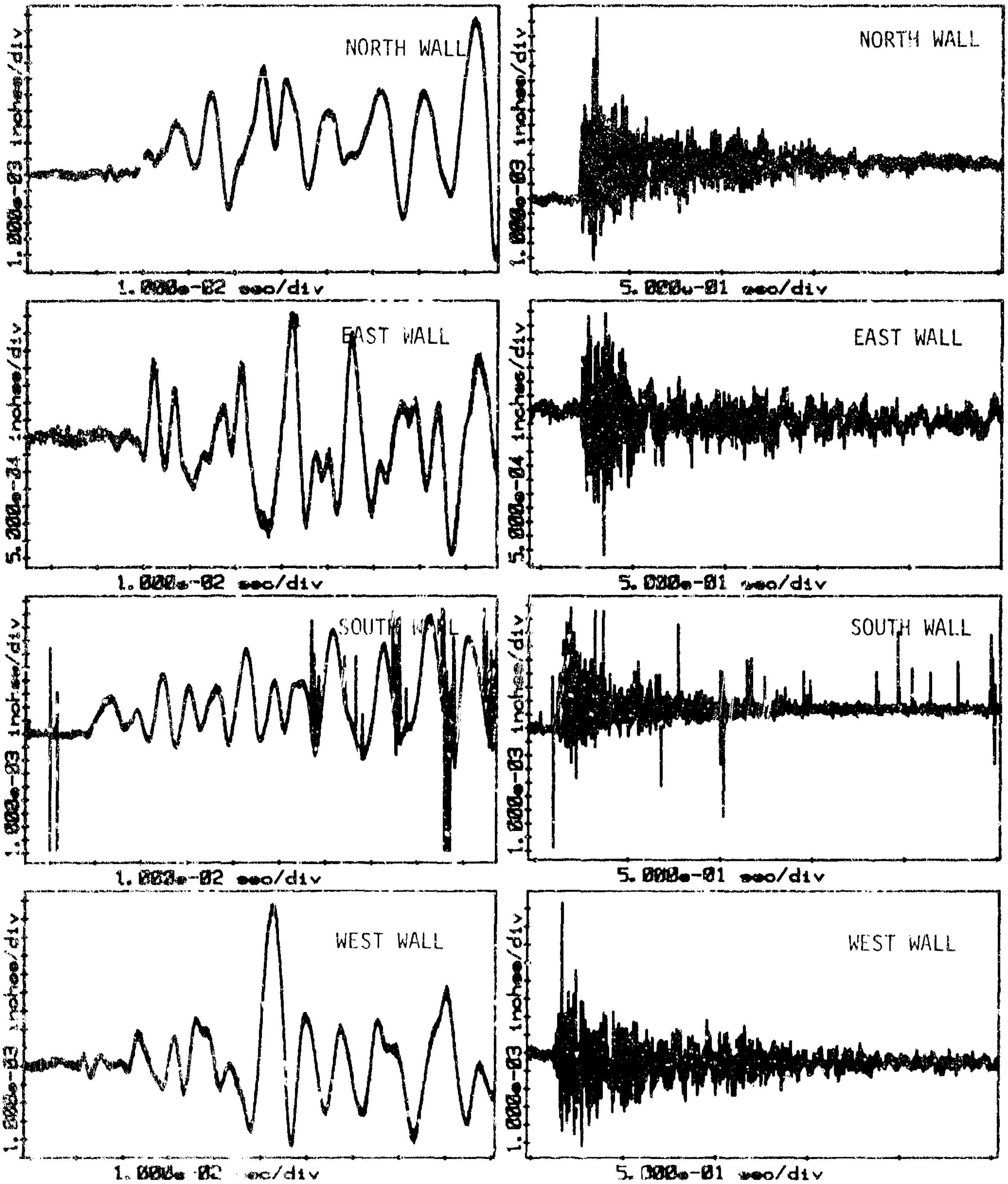


FIGURE A-4. DISPLACEMENT-TIME HISTORIES FOR SHOT 2305

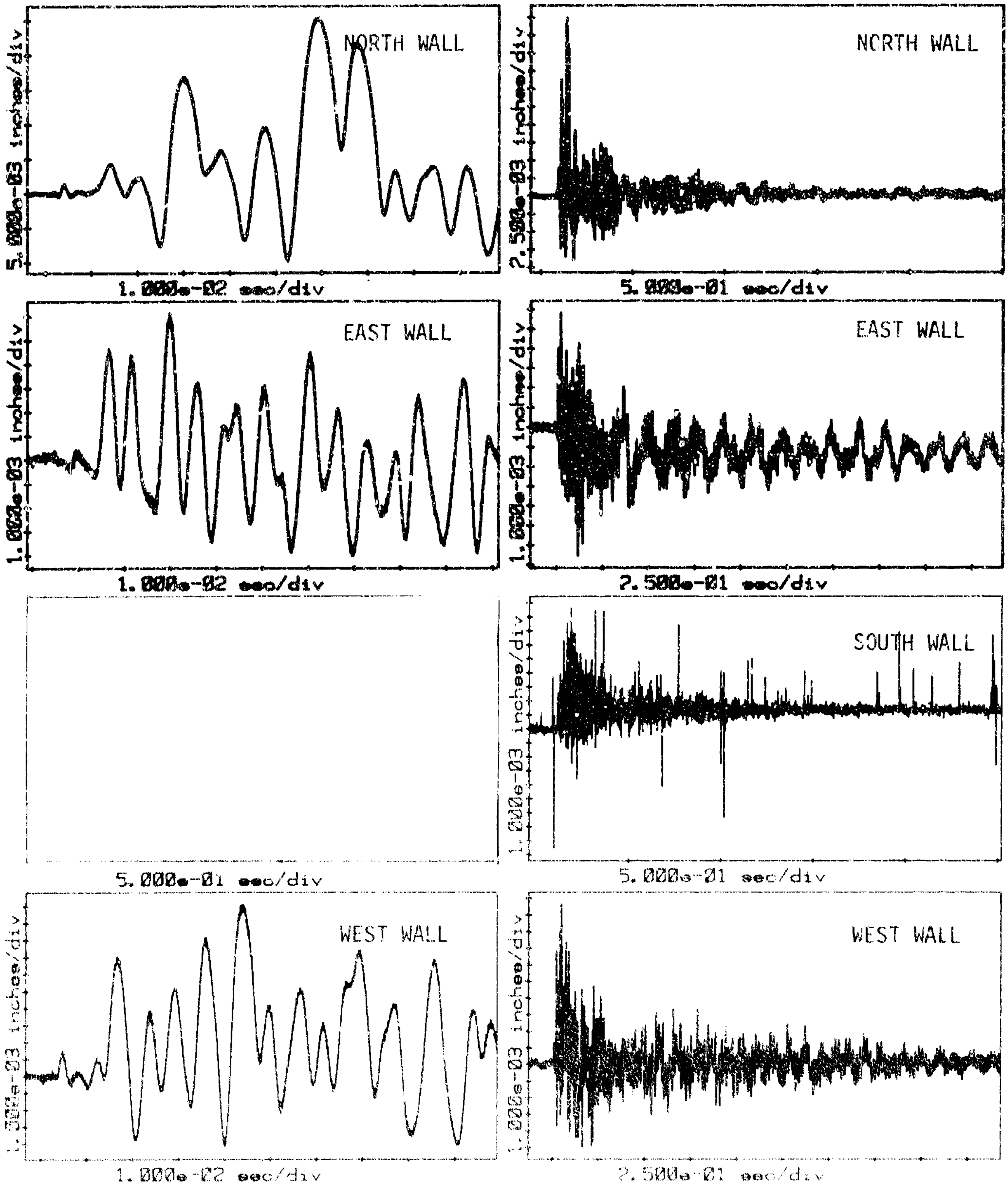


FIGURE A-5. DISPLACEMENT-TIME HISTORIES FOR SHOT 2306

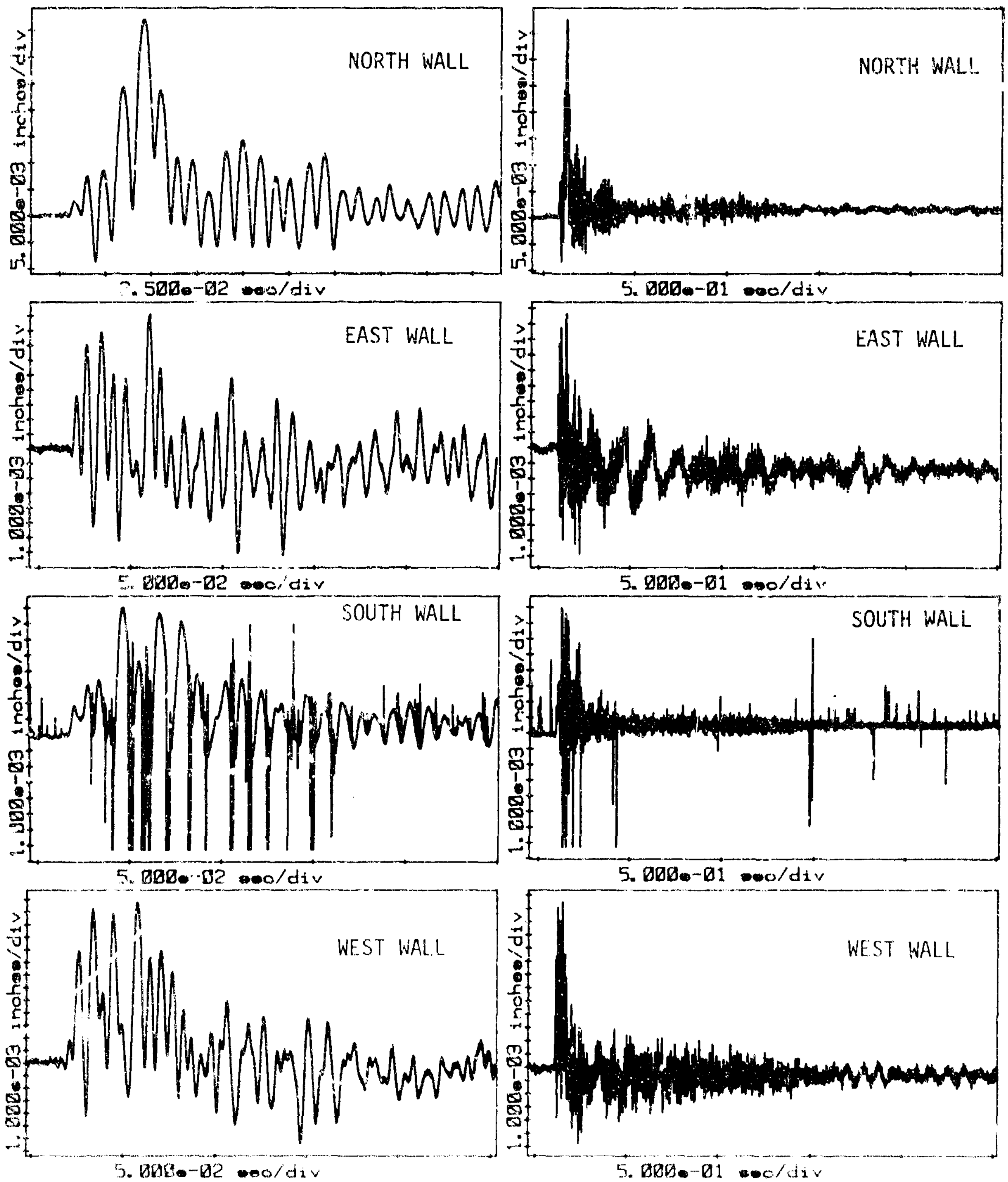


FIGURE A-6. DISPLACEMENT-TIME HISTORIES FOR SHOT 2307

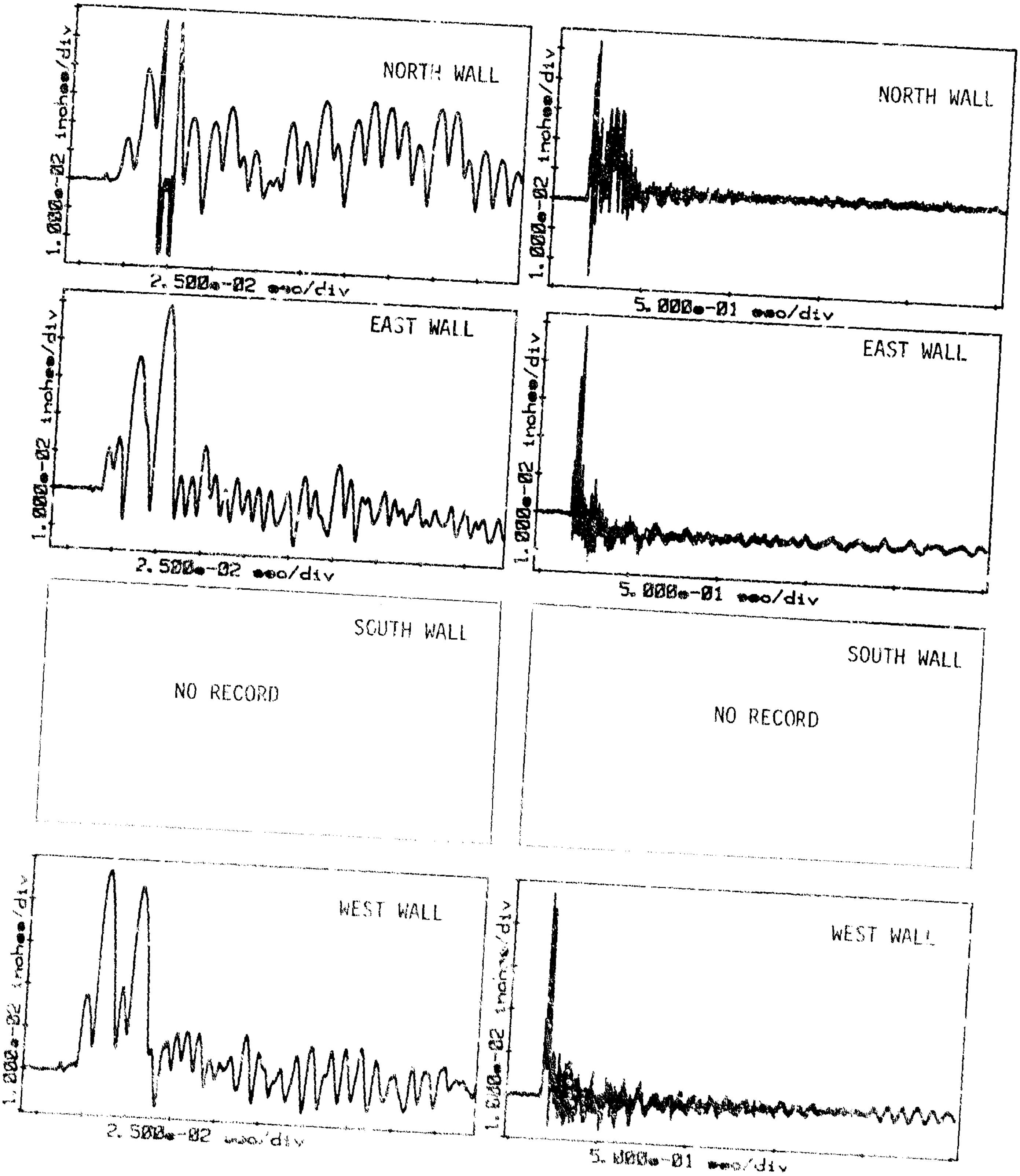


FIGURE A-7. DISPLACEMENT-TIME HISTORIES FOR SHOT 2308

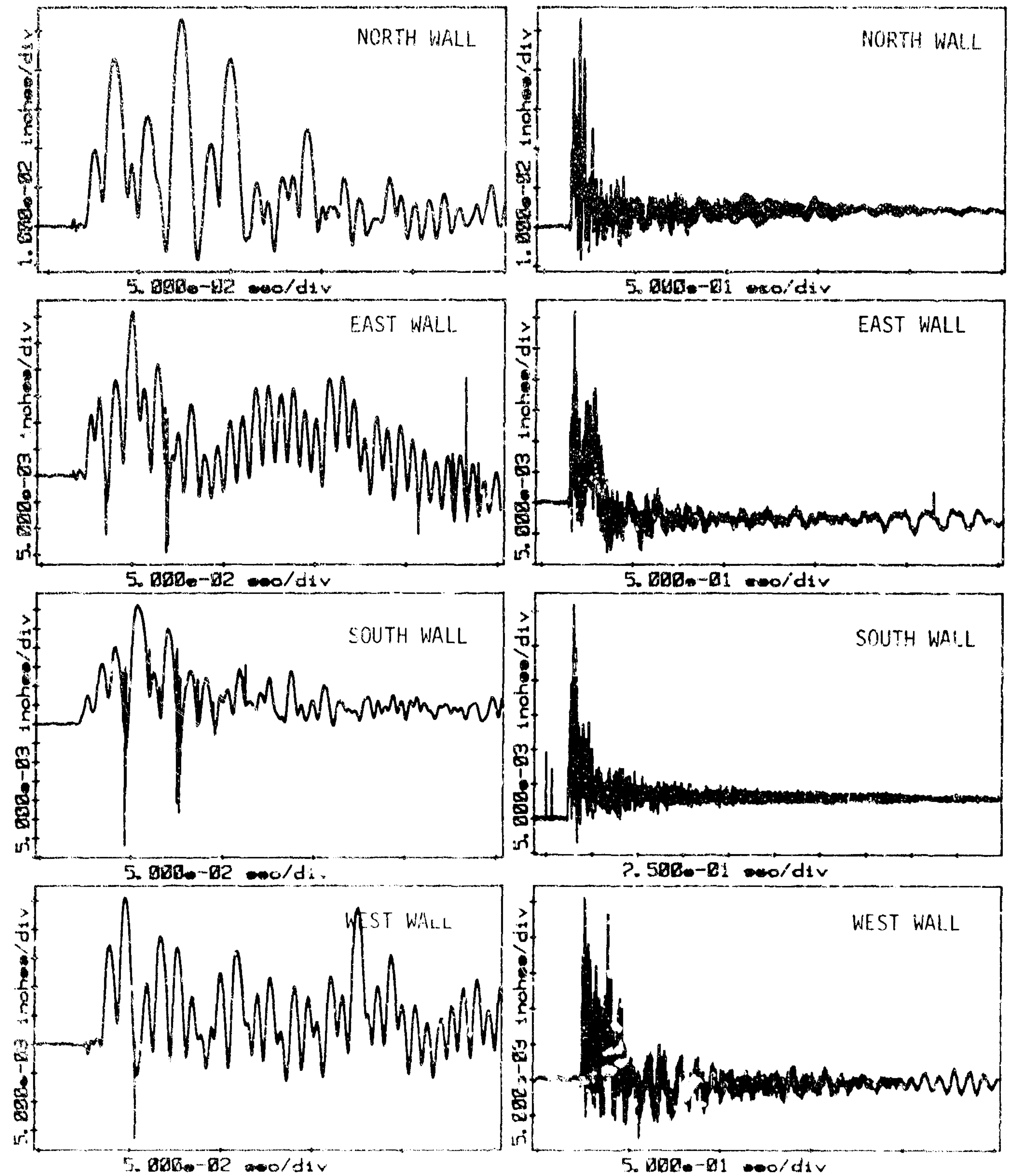


FIGURE A-8. DISPLACEMENT TIME HISTORIES FOR SHOT 2309

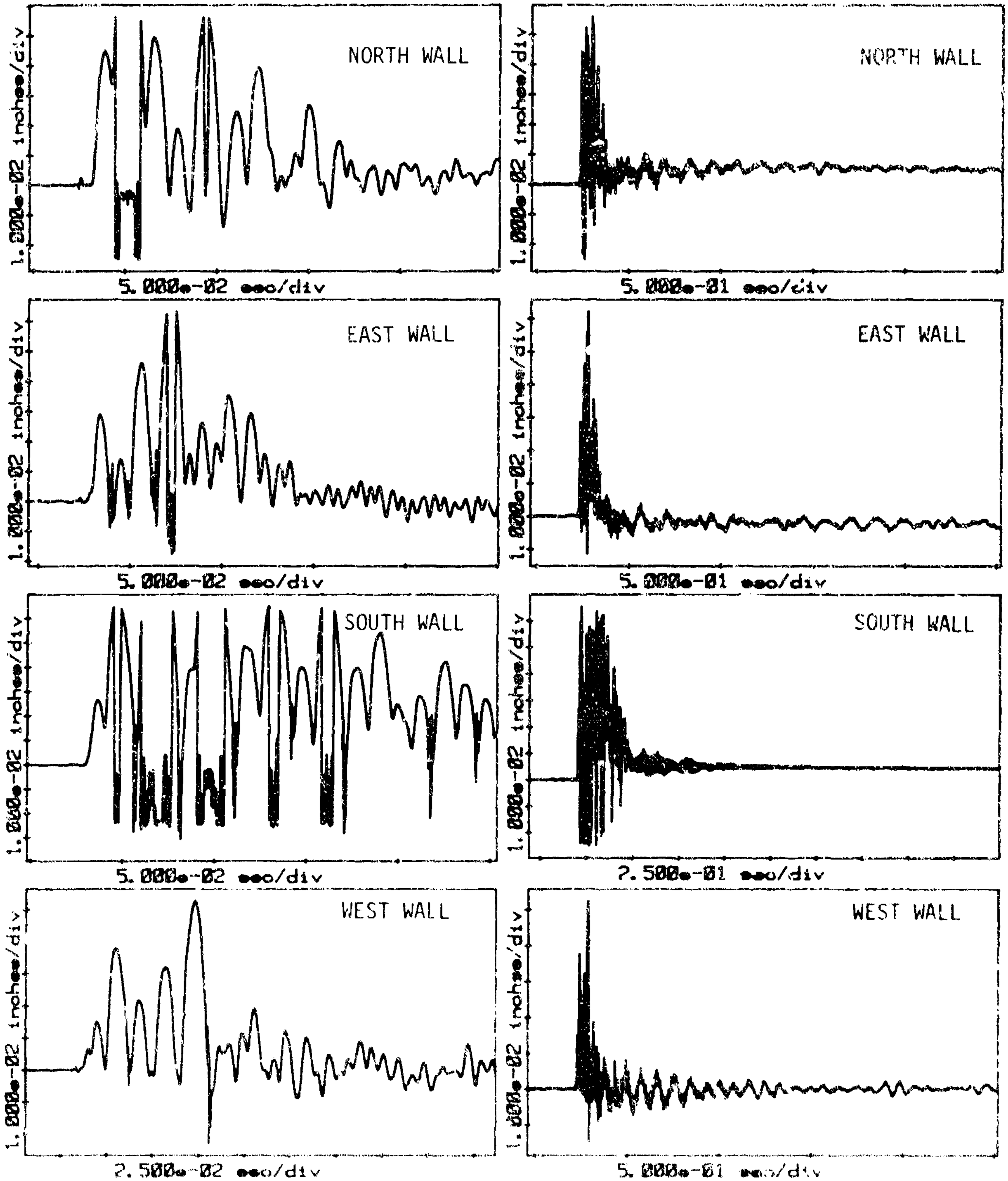


FIGURE A-9. DISPLACEMENT-TIME HISTORIES FOR SHOT 2310

APPENDIX B

FLOOR MOTION-TIME HISTORIES AND THEIR FOURIER SPECTRUM PLOTS

Top Plot	Channel 9	Transverse
Middle Plot	Channel 10	Vertical
Bottom Plot	Channel 11	Radial

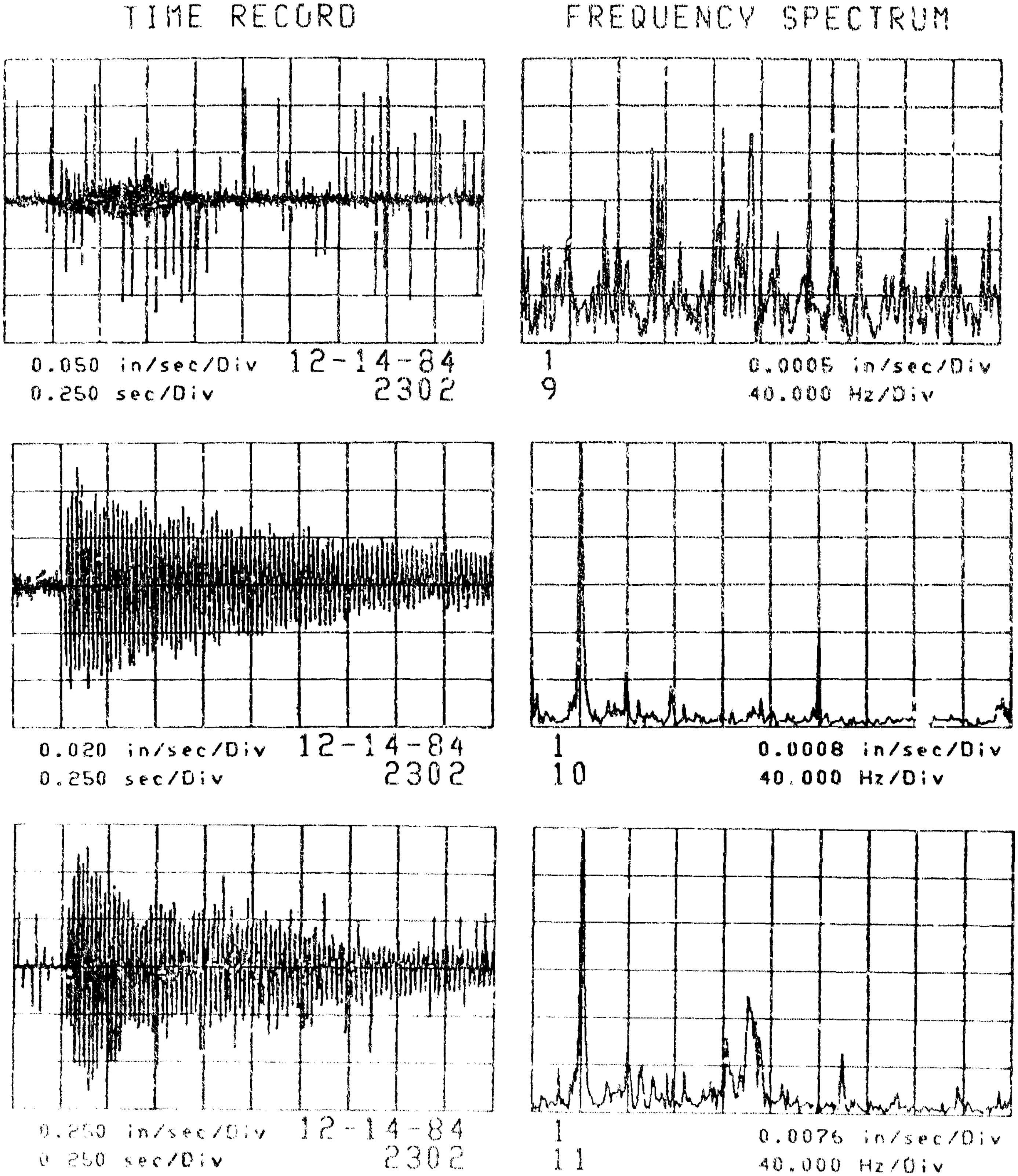
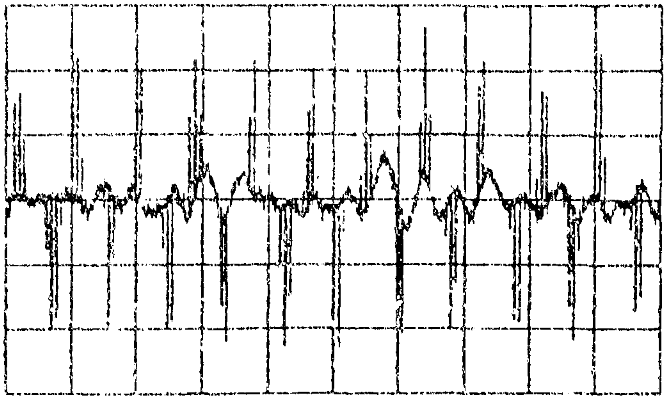
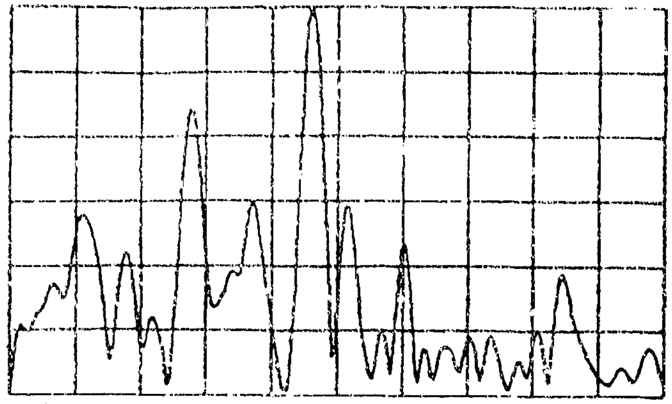


FIGURE B-1. FLOOR MOTION-TIME HISTORIES FOR SHOT 2302

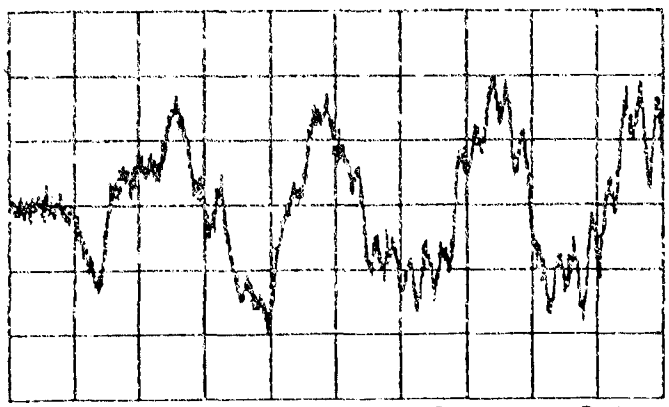
TIME RECORD FREQUENCY SPECTRUM



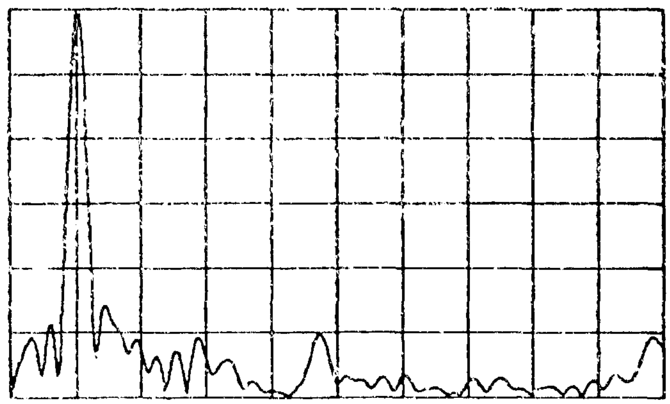
0.050 in/sec/Div 12-14-84
0.010 sec/Div 2302



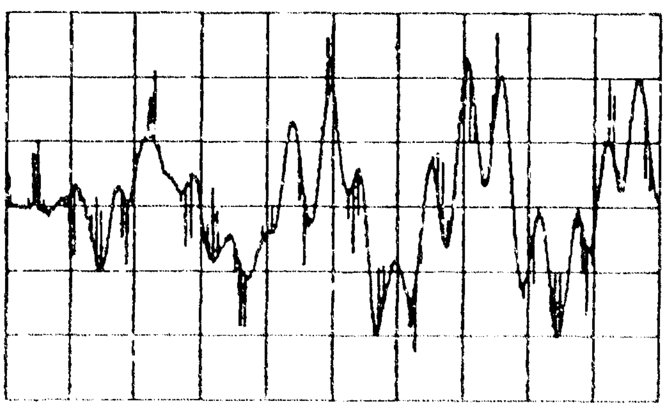
1
9
0.0012 in/sec/Div
40.000 Hz/Div



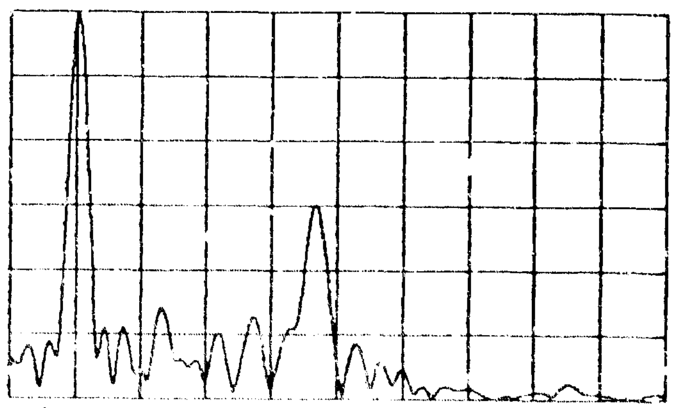
0.050 in/sec/Div 12-14-84
0.010 sec/Div 2302



1
10
0.0095 in/sec/Div
40.000 Hz/Div



0.100 in/sec/Div 12-14-84
0.010 sec/Div 2302



1
11
0.[illegible]51 in/sec/Div
40.000 Hz/Div

FIGURE B-1. FLOOR MOTION-TIME HISTORIES FOR SHOT 2302 (Cont.)

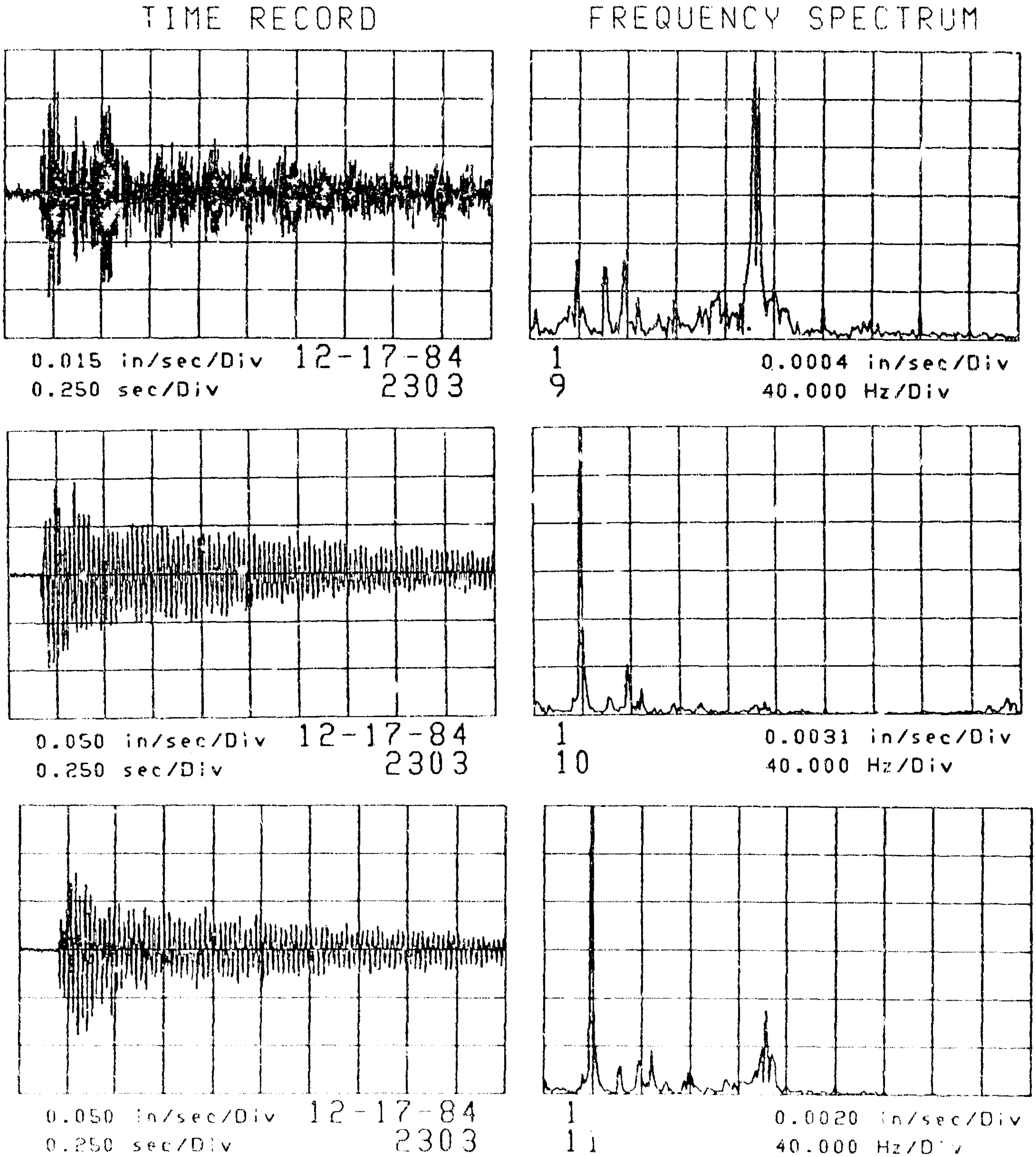


FIGURE B-2. FLOOR MOTION-TIME HISTORIES FOR SHOT 2303

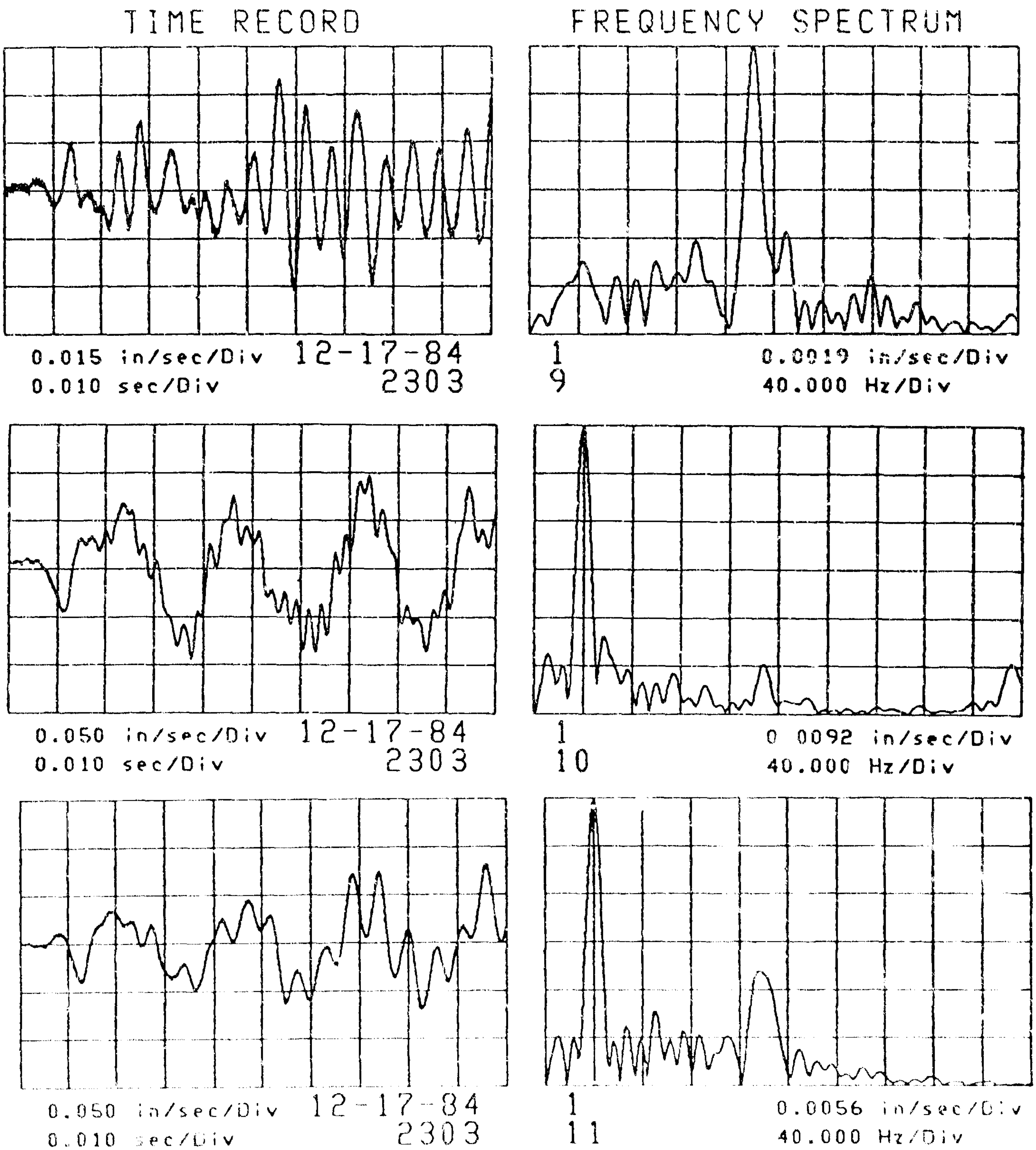


FIGURE B-2. FLOOR MOTION-TIME HISTORIES FOR SHOT 2303 (Cont.)

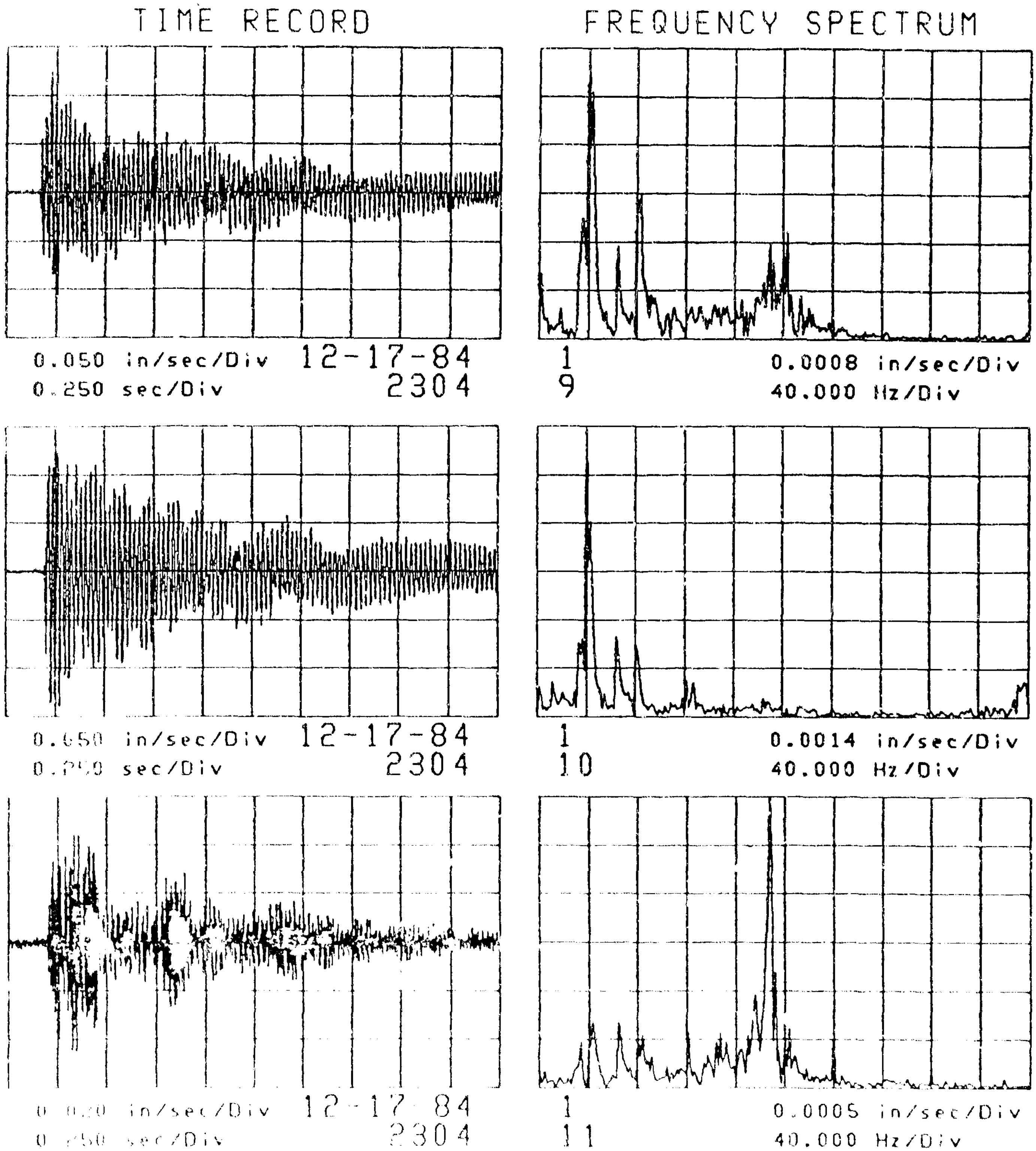


FIGURE B-3 FLOOR MOTION-TIME HISTORIES FOR SHOT 2304

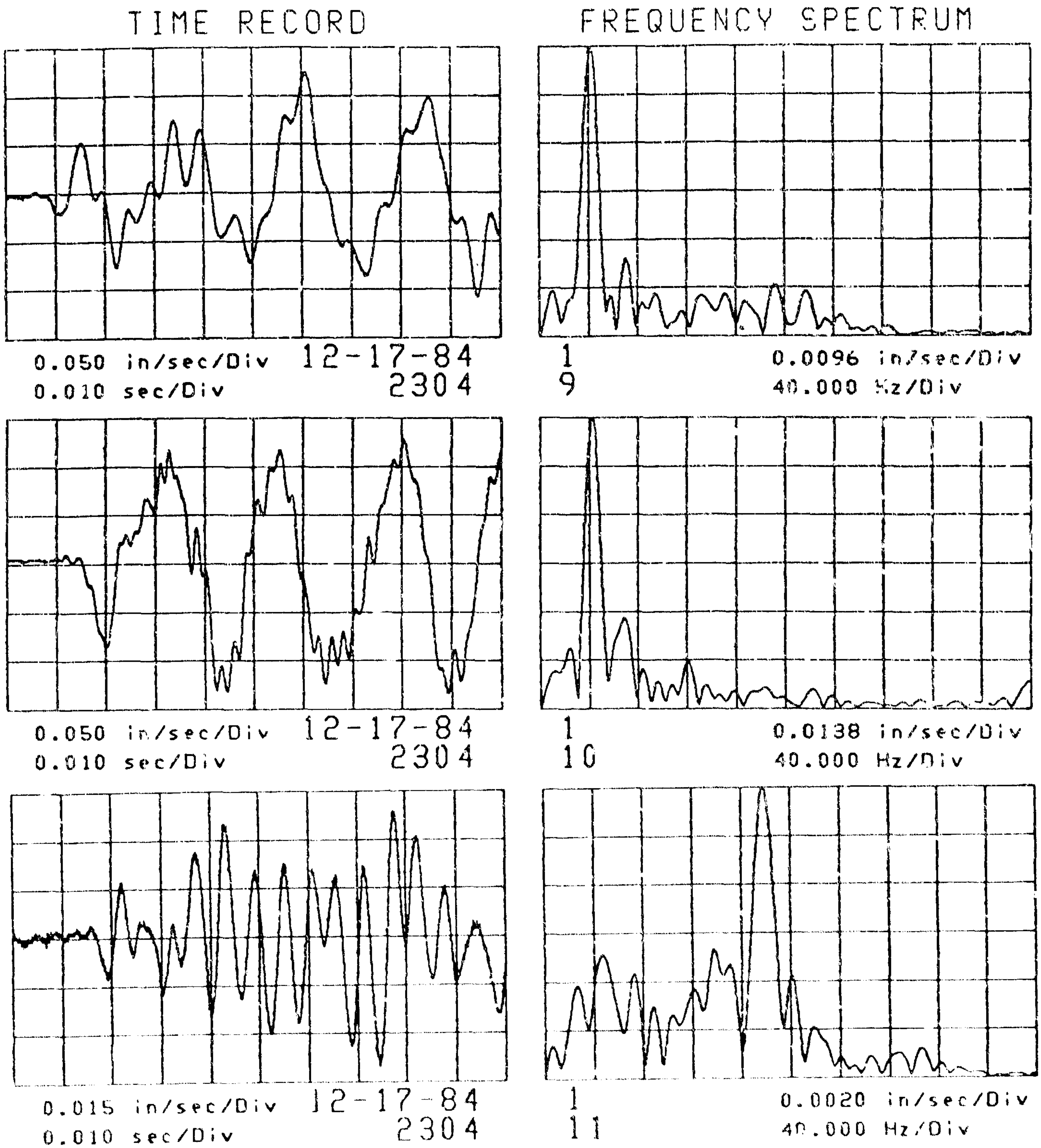


FIGURE B-3. FLOOR MOTION-TIME HISTORIES FOR SHOT 2304 (Cont.)

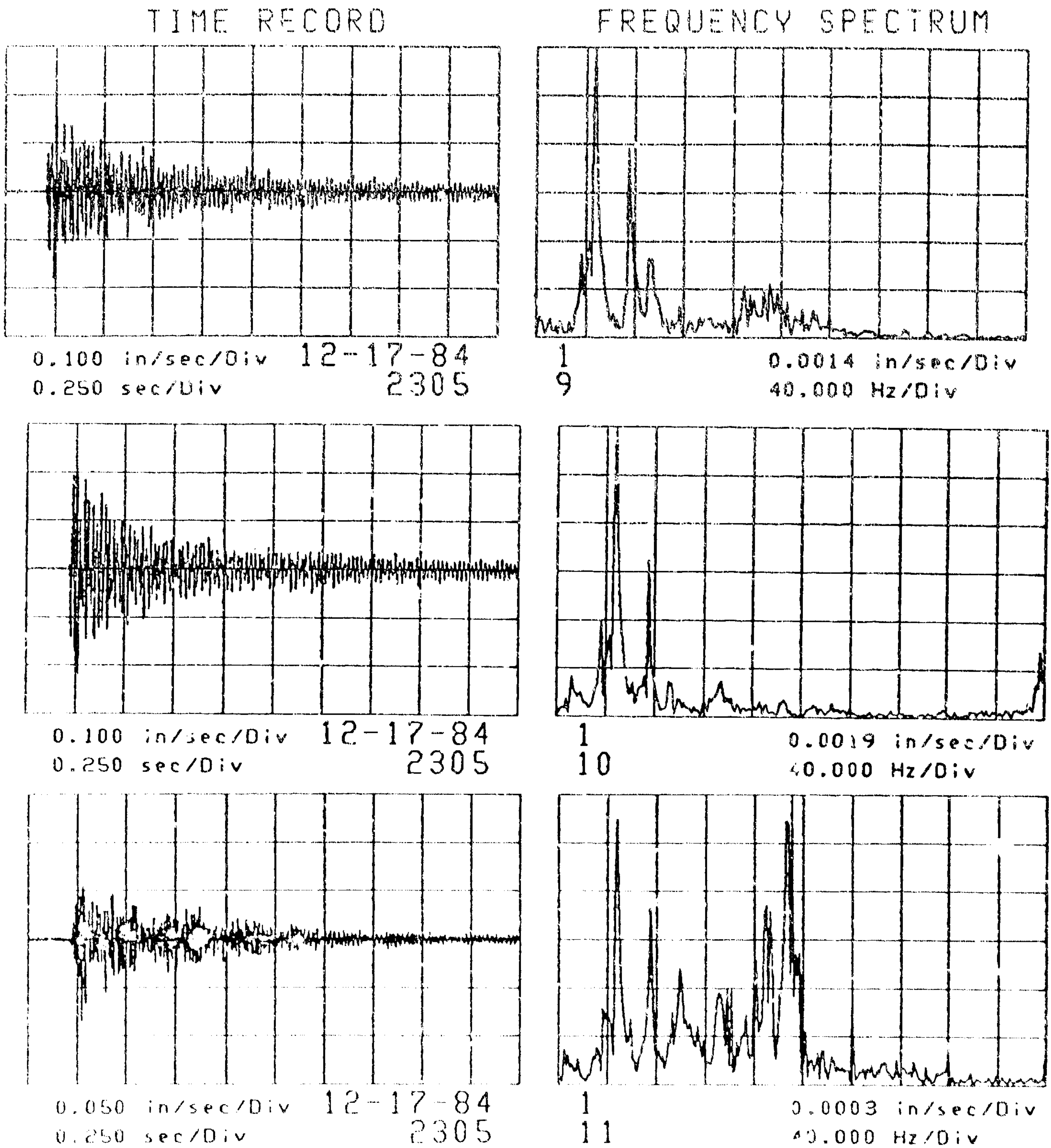


FIGURE B-4. FLOOR MOTION TIME HISTORIES FOR SHOT 2305

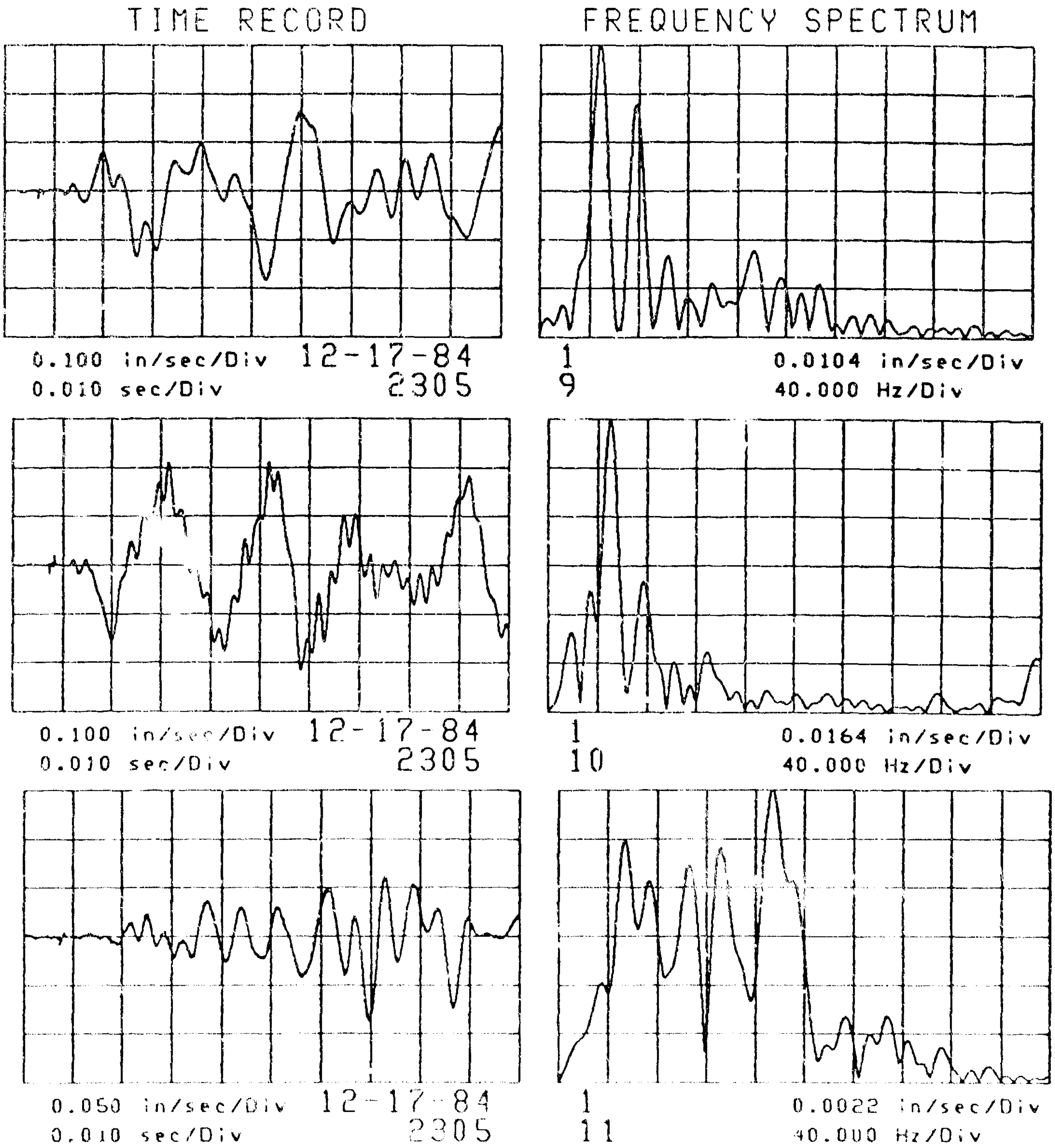


FIGURE B-4. FLOOR MOTION-TIME HISTORIES FOR SHOT 2305 (Cont.)

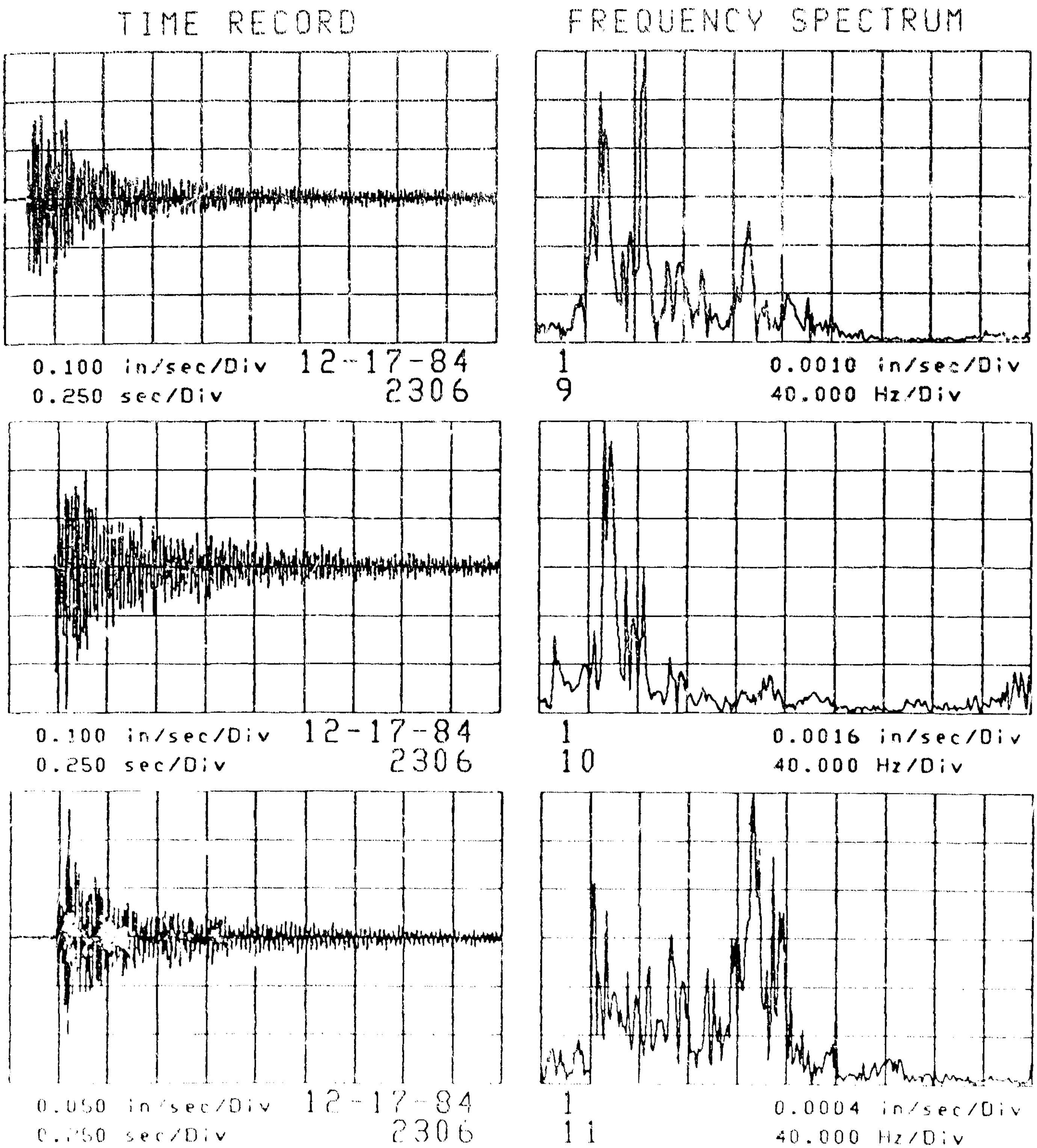


FIGURE B-5. FLOOR MOTION-TIME HISTORIES FOR SHOT 2306

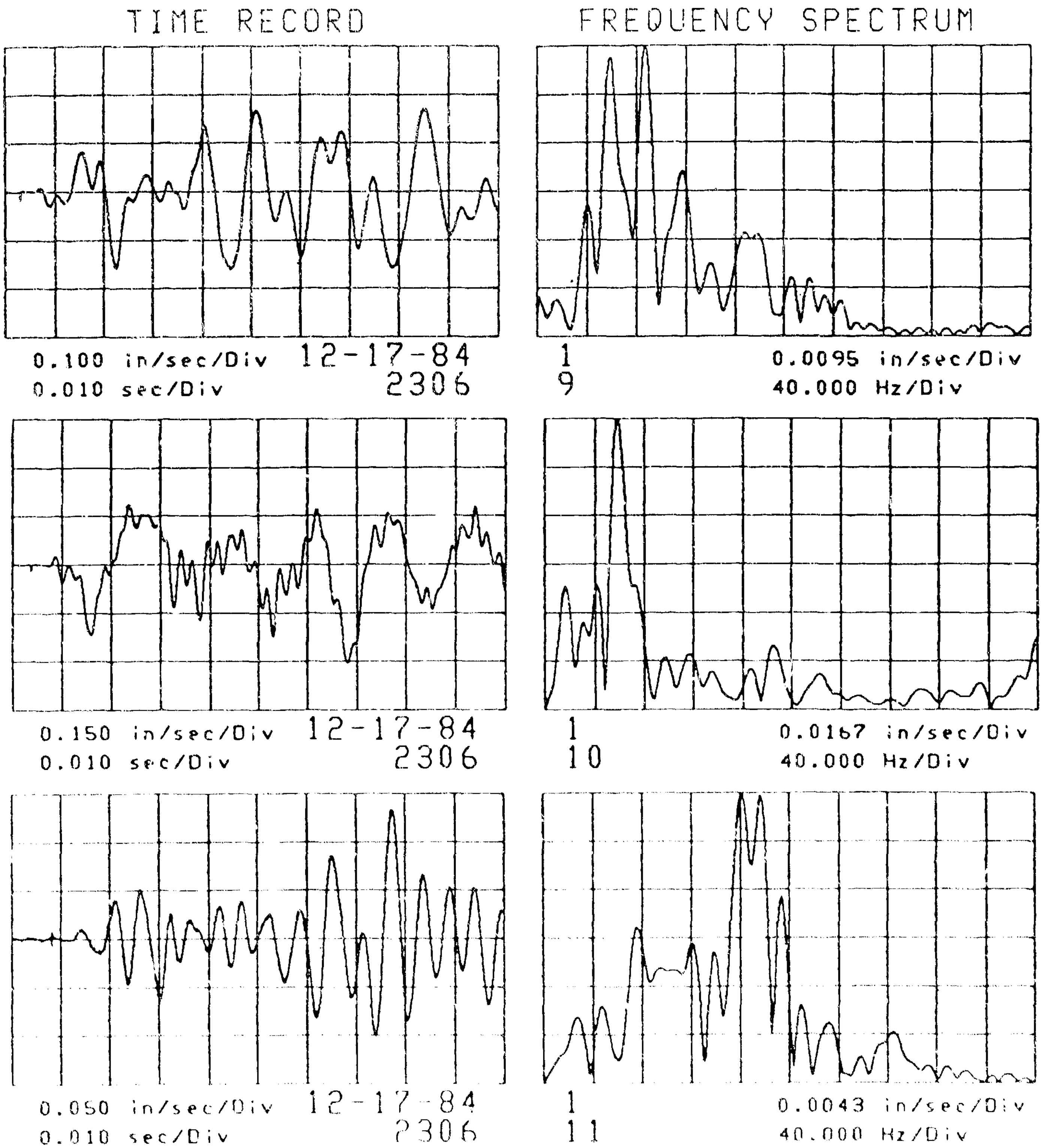


FIGURE B-5. FLOOR MOTION TIME HISTORIES FOR SHOT 2306 (Cont.)

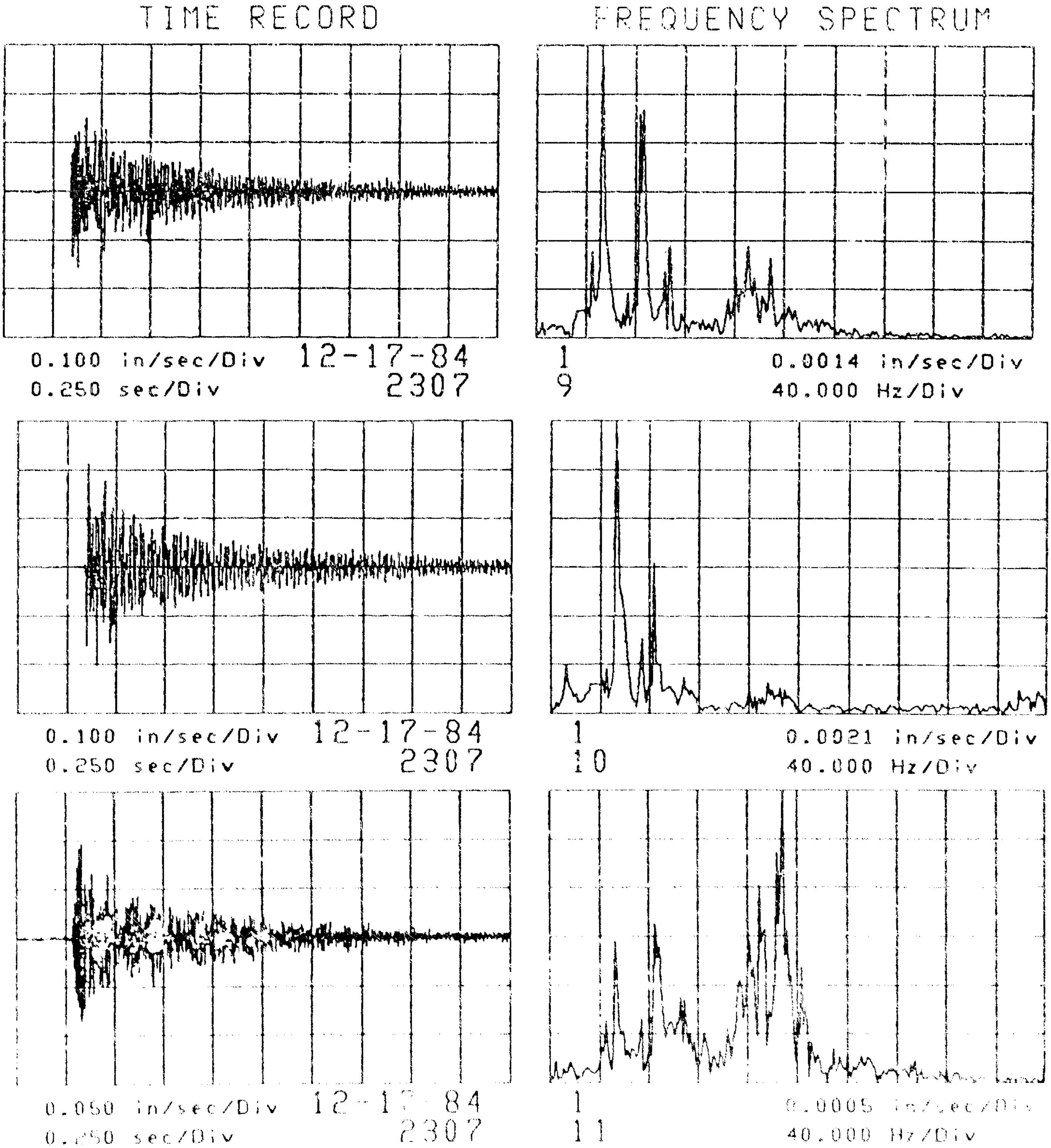


FIGURE B-6. FLOOR MOTION TIME HISTORIES FOR SHOT 2307

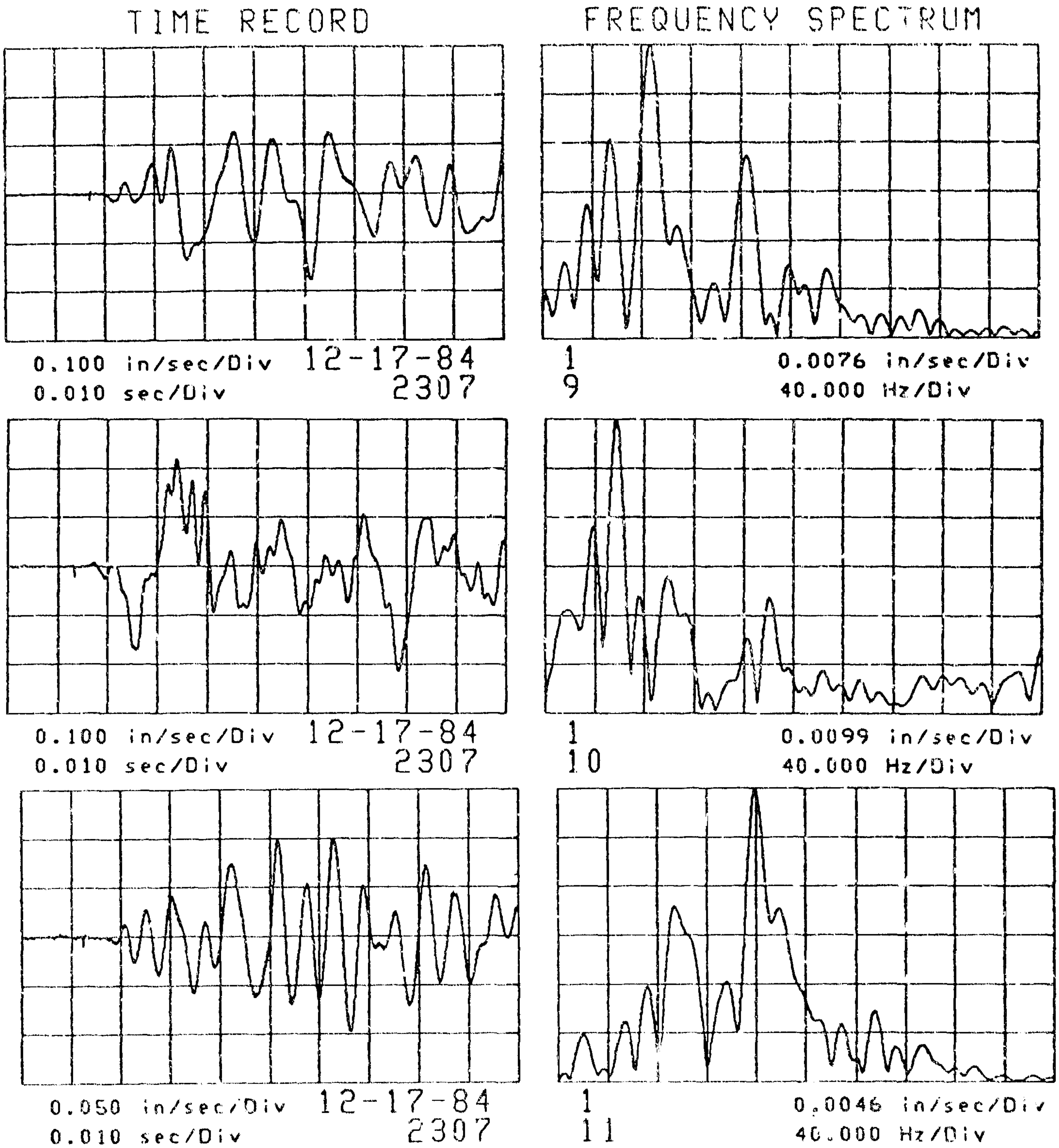


FIGURE B-6. FLOOR MOTION-TIME HISTORIES FOR SHOT 2307 (Cont.)

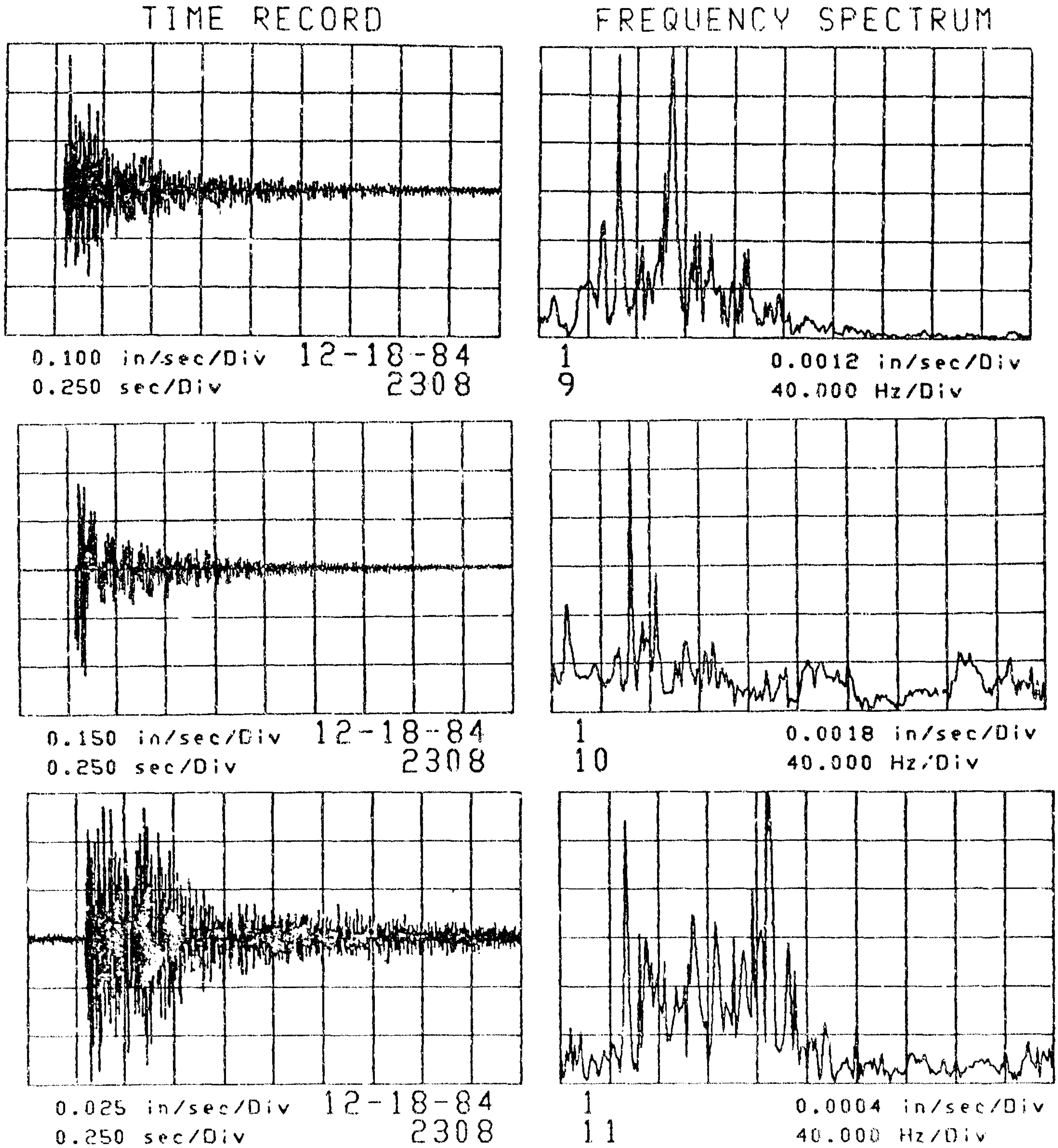


FIGURE B-7. FLOOR MOTION-TIME HISTORIES FOR SHOT 2308

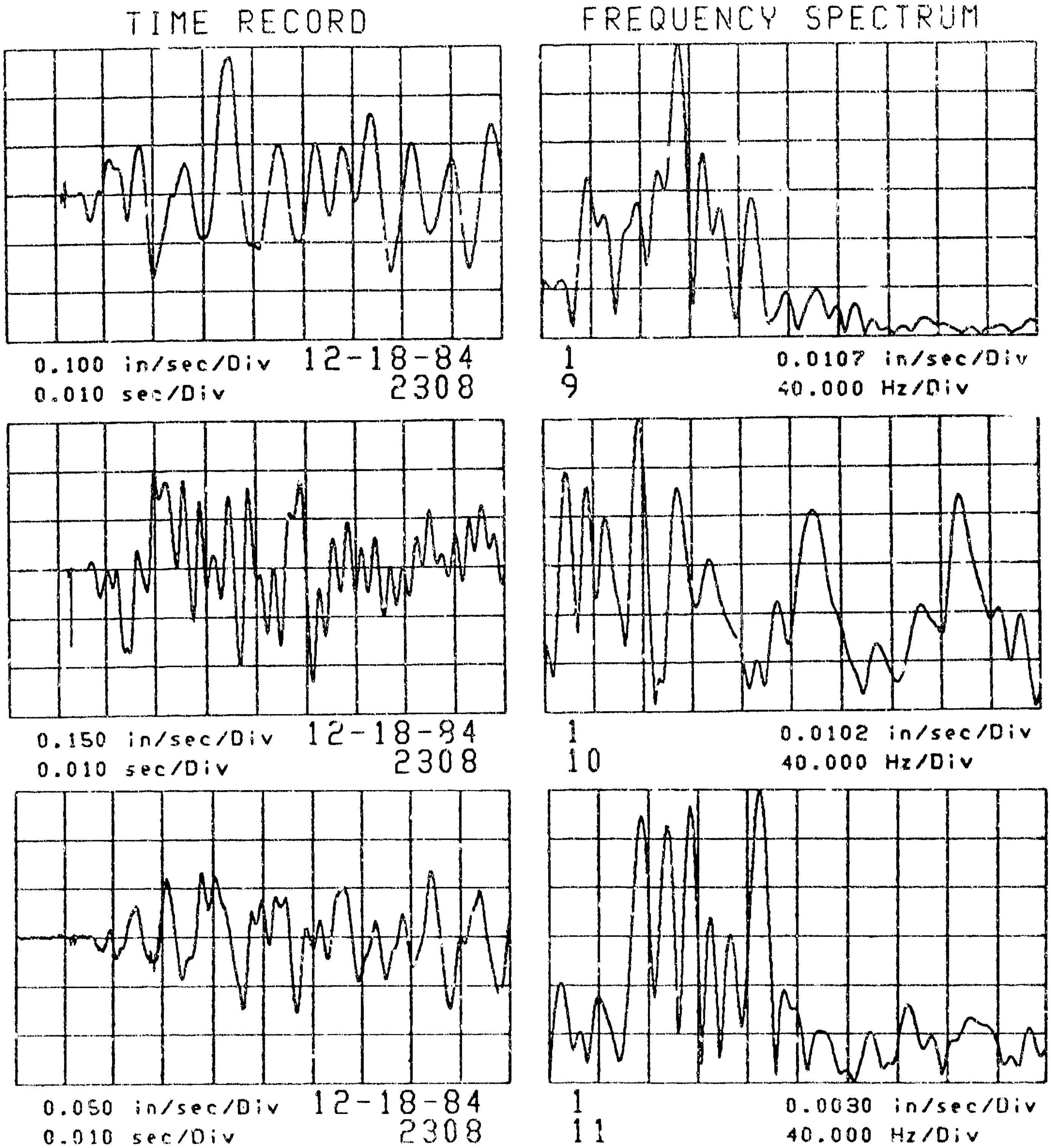


FIGURE B-7. FLOOR MOTION-TIME HISTORIES FOR SHOT 2308 (Cont.)

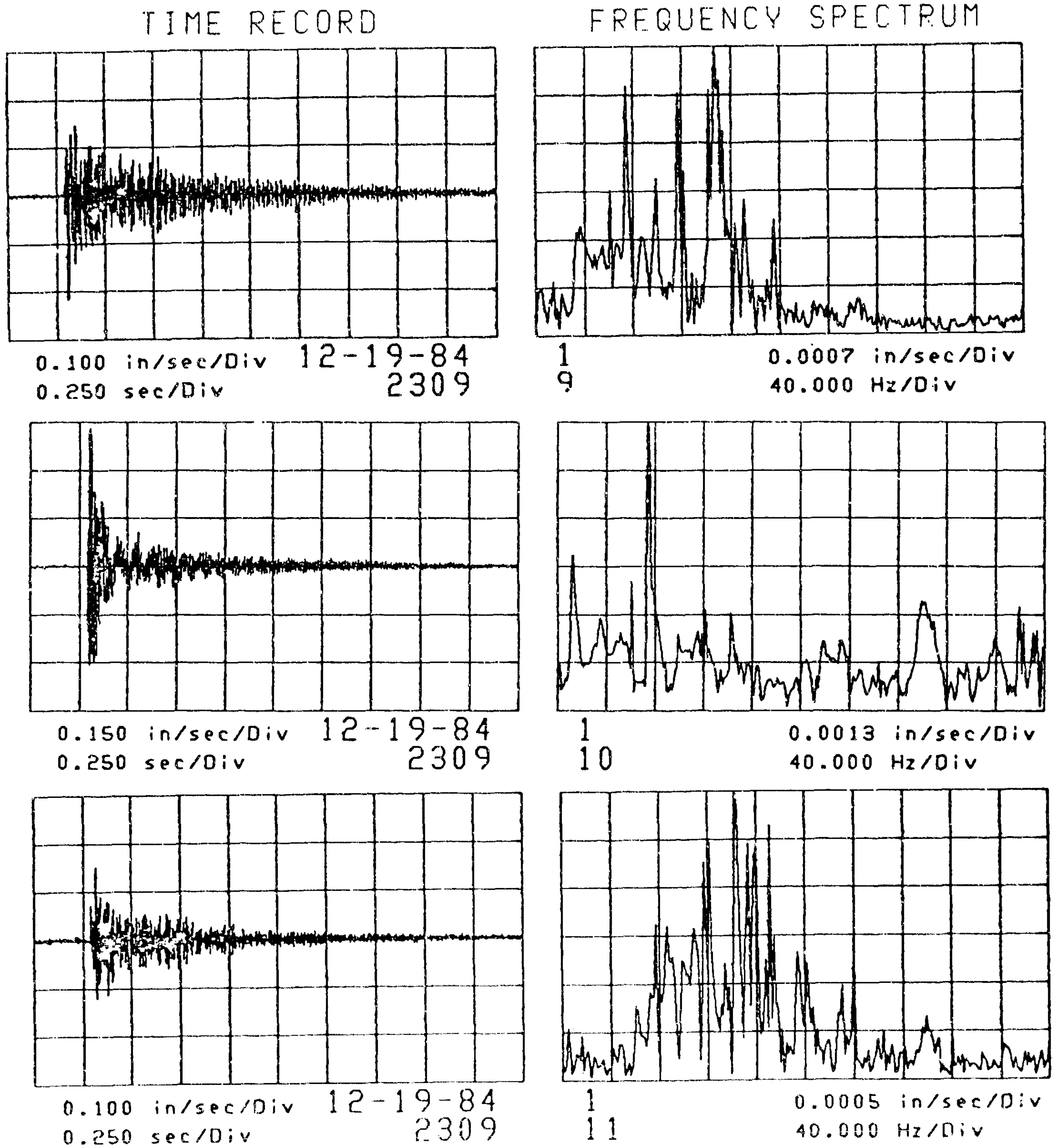


FIGURE B-8. FLOOR MOTION-TIME HISTORIES FOR SHOT 2309

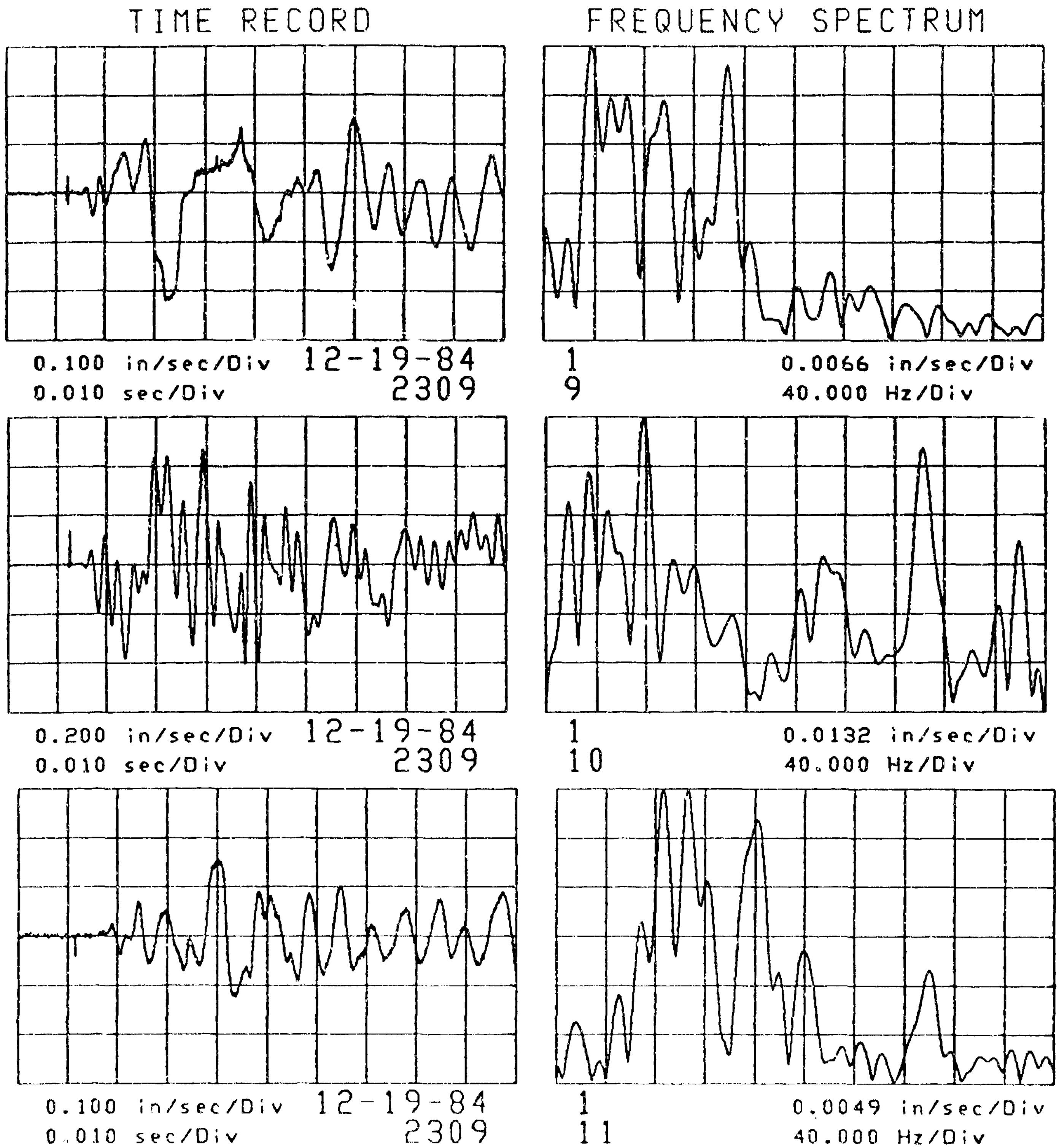


FIGURE B-8. FLOOR MOTION-TIME HISTORIES FOR SHOT 2309 (Cont.)

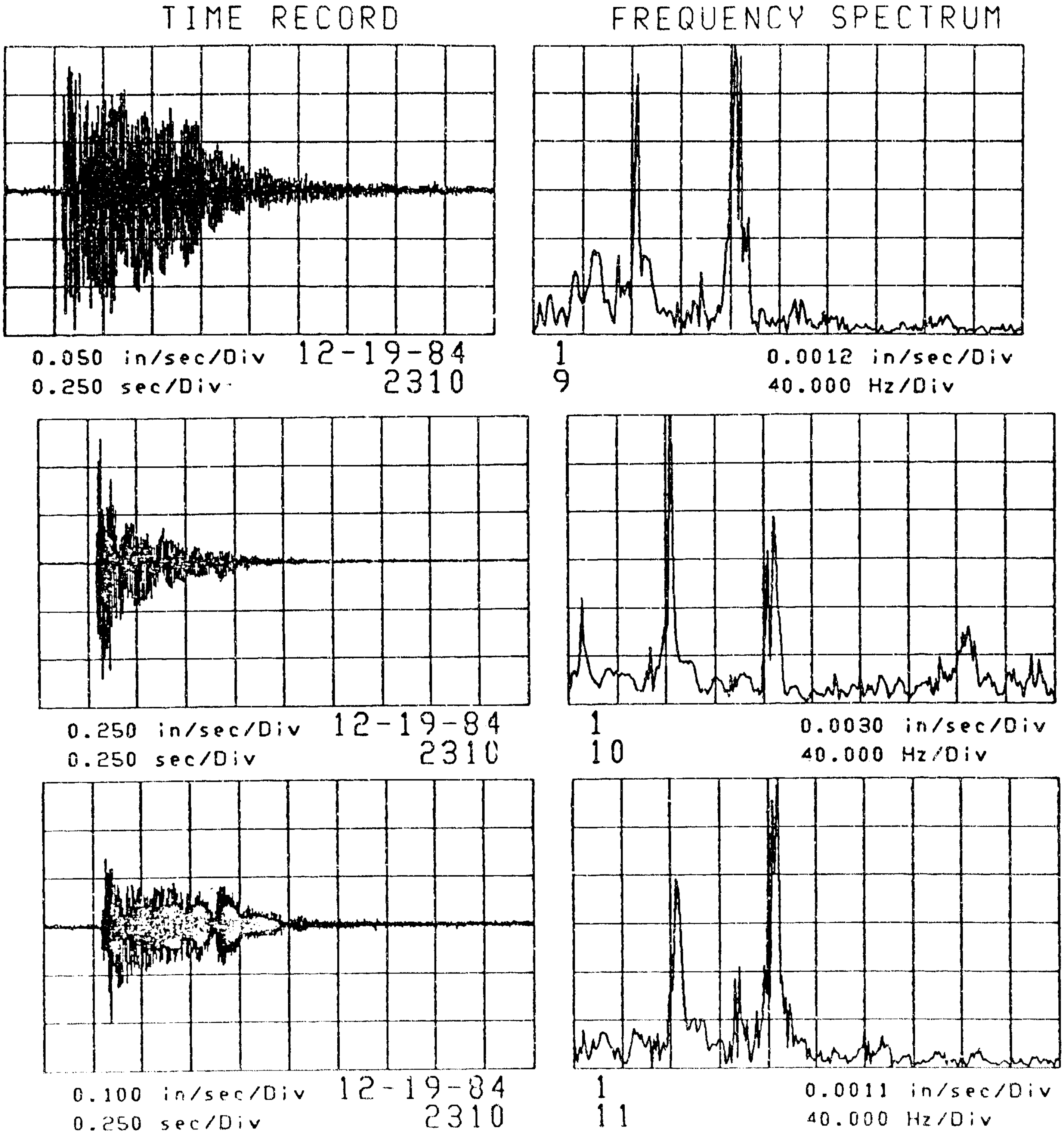


FIGURE B-9. FLOOR MOTION-TIME HISTORIES FOR SHOT 2310

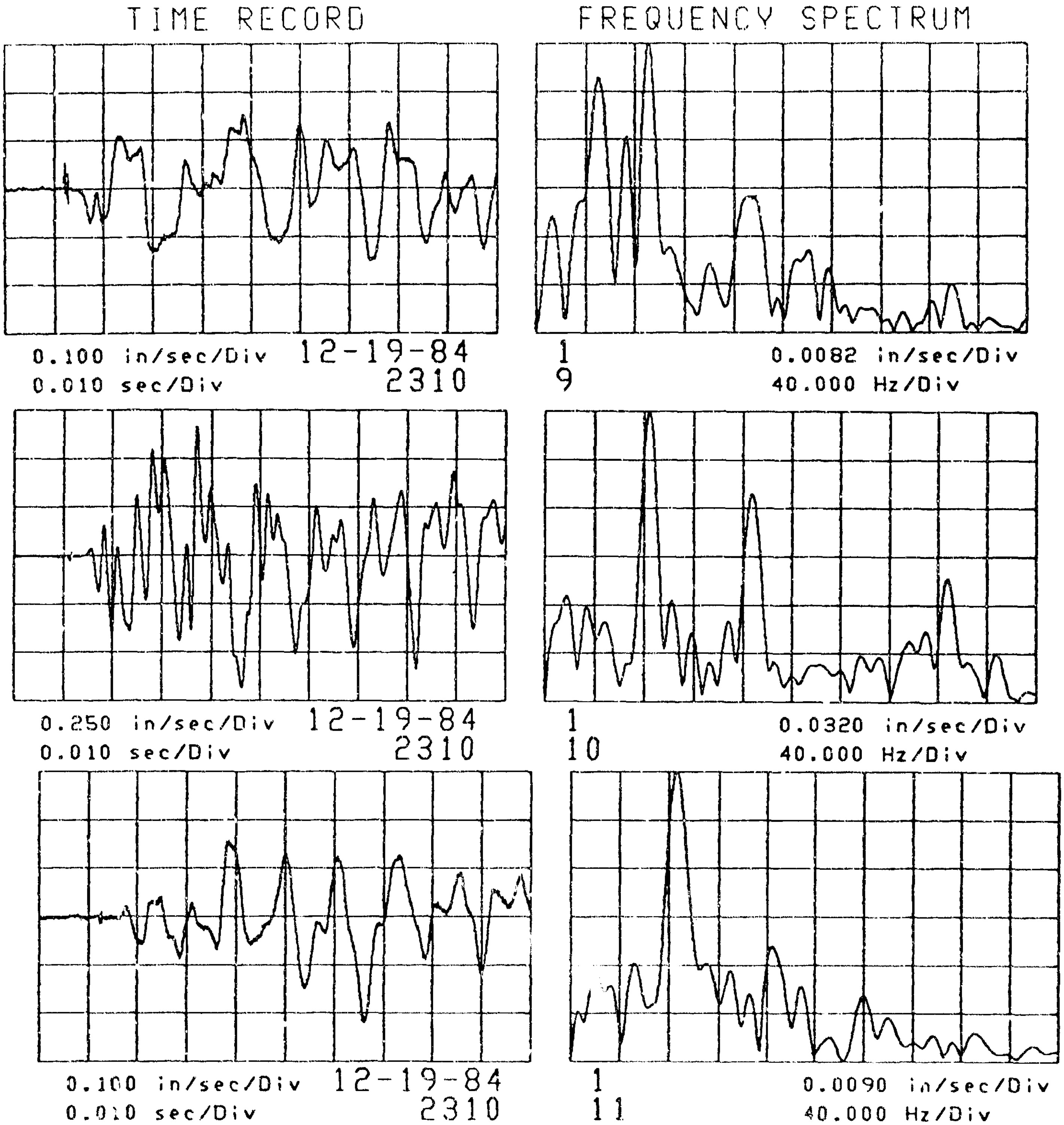


FIGURE B-9. FLOOR MOTION-TIME HISTORIES FOR SHOT 2310 (Cont.)

APPENDIX C

SOUND/NOISE PRESSURE-TIME HISTORIES AND THEIR FOURIER SPECTRA

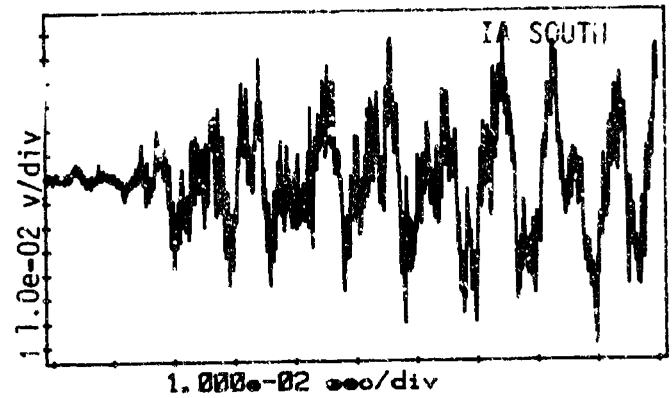


FIGURE C-1. SOUND LEVEL READINGS FOR SHOT 2302

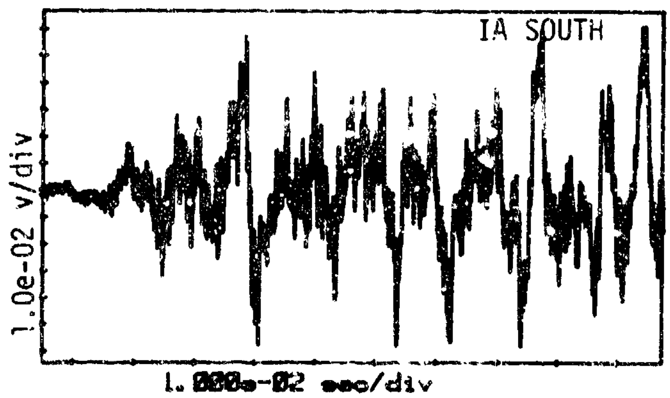


FIGURE C-2. SOUND LEVEL READINGS FOR SHOT 2303

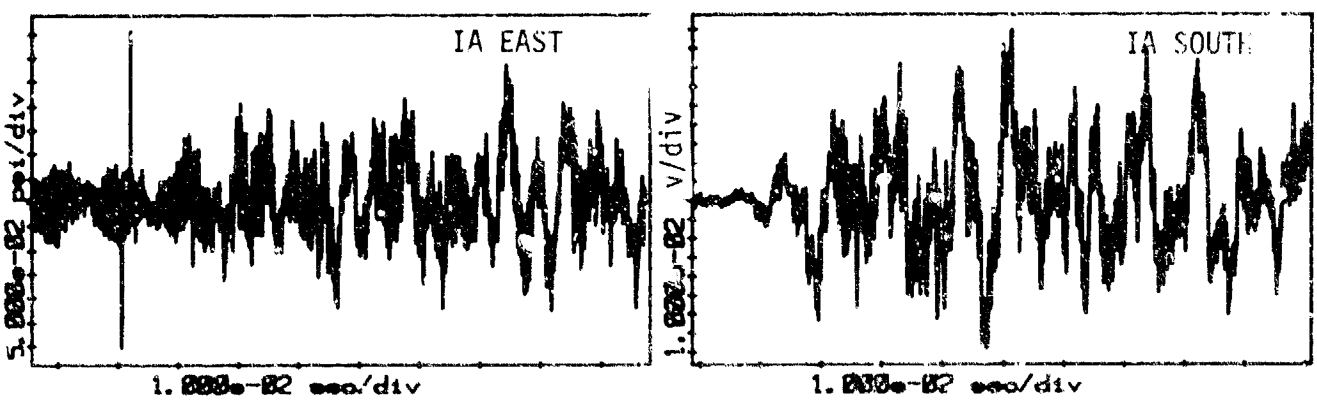


FIGURE C-3. SOUND LEVEL READINGS FOR SHOT 2304

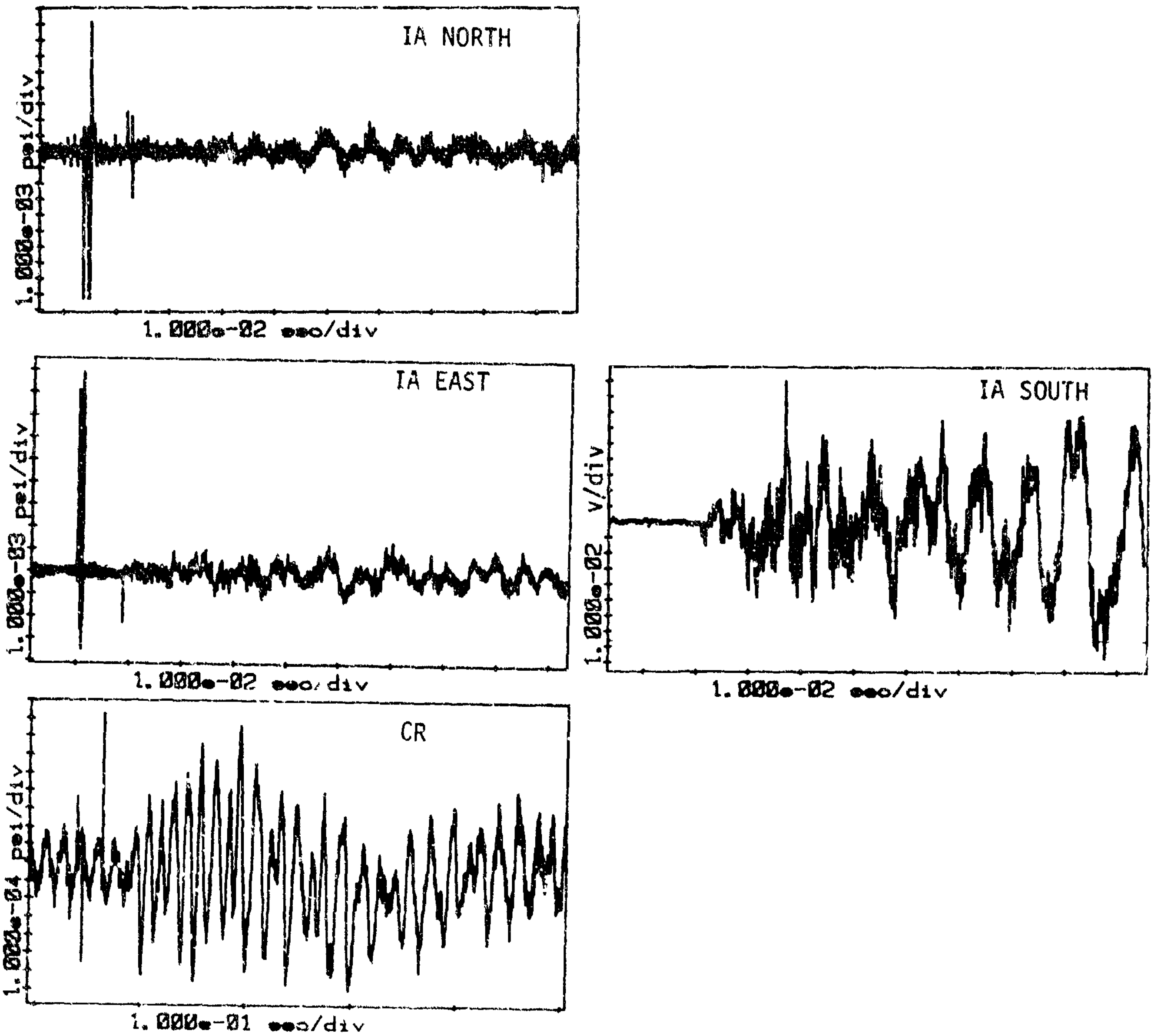


FIGURE C-4. SOUND LEVEL READINGS FOR SHOT 2305

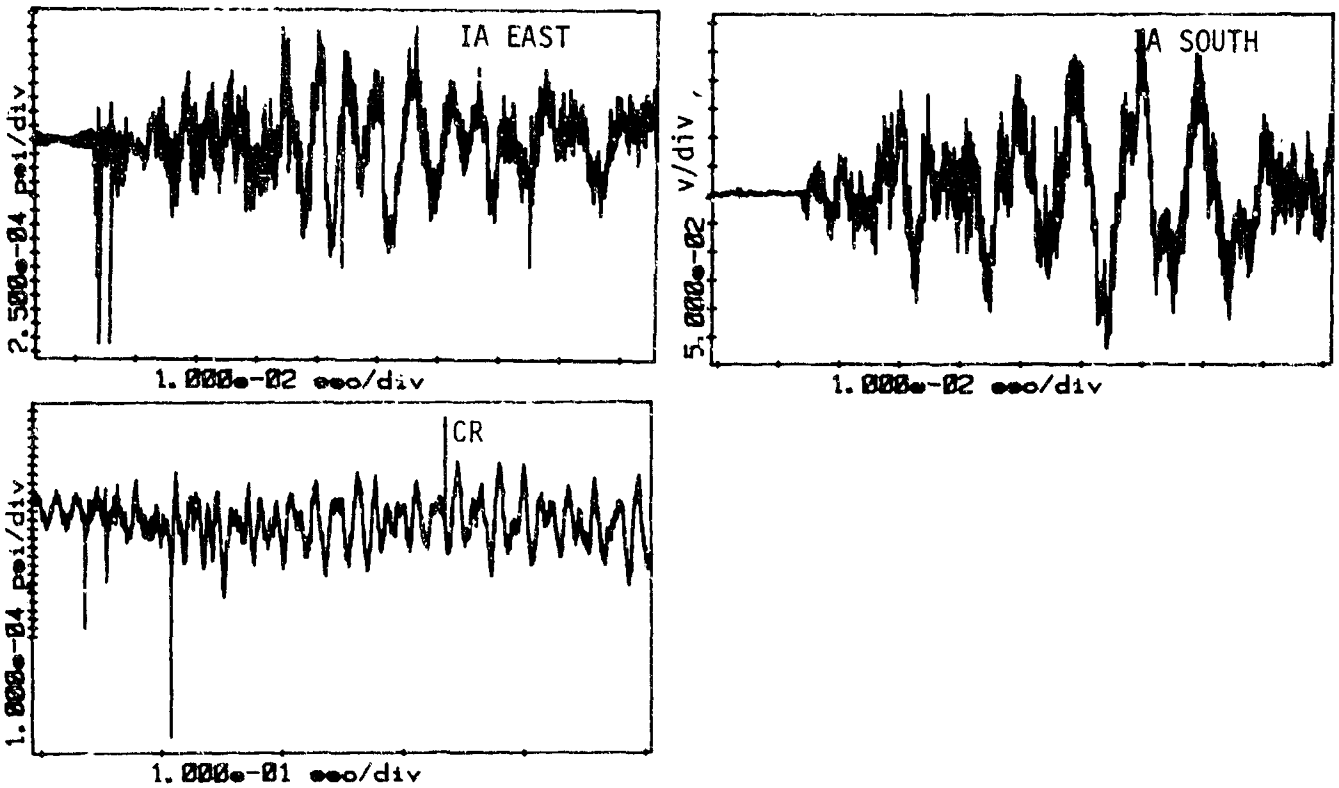


FIGURE C-5. SOUND LEVEL READINGS FOR SHOT 2306

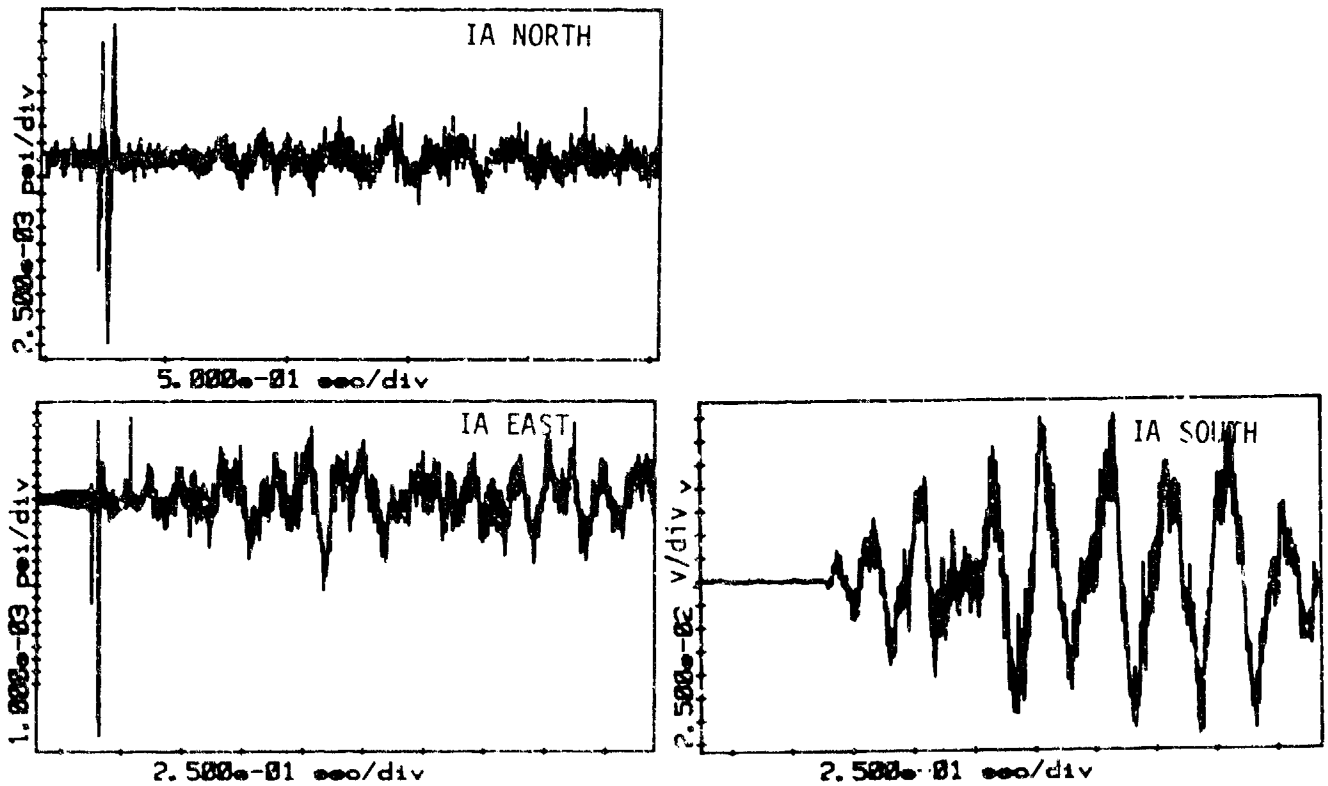


FIGURE C-6. SOUND LEVEL READINGS FOR SHOT 2307

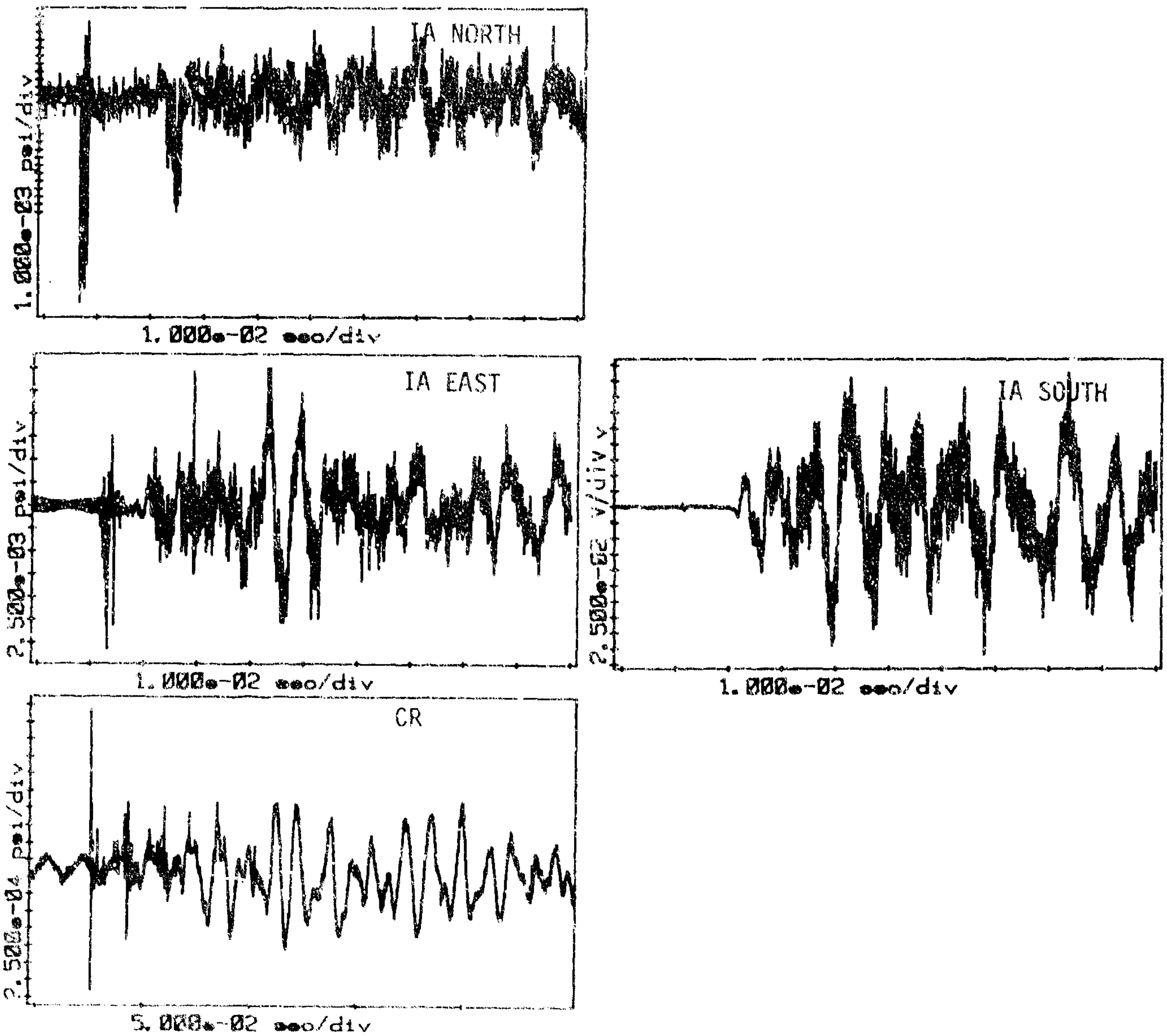


FIGURE C-7. SOUND LEVEL READINGS FOR SHOT 2308

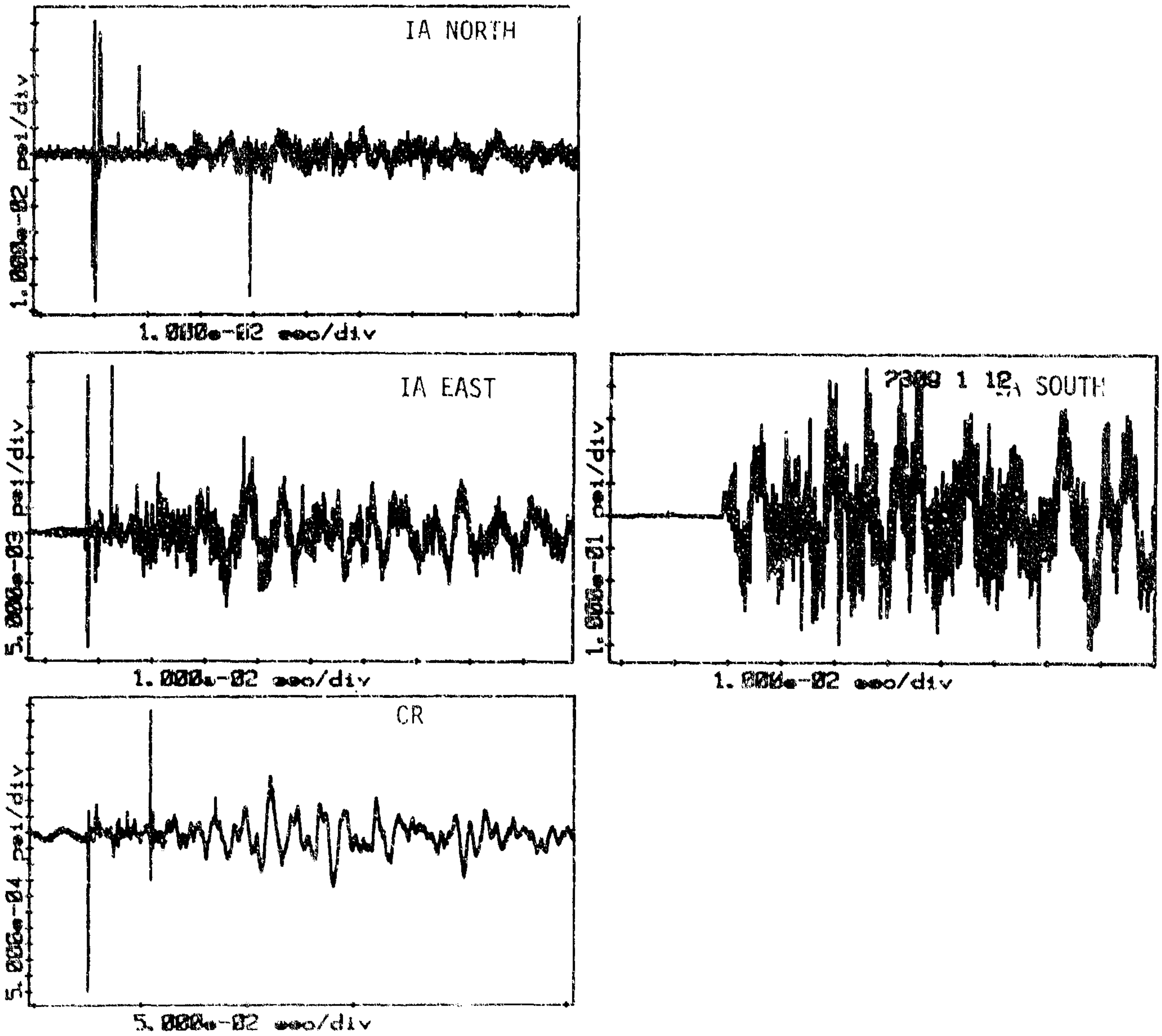


FIGURE C-8. SOUND LEVEL READINGS FOR SHOT 2309

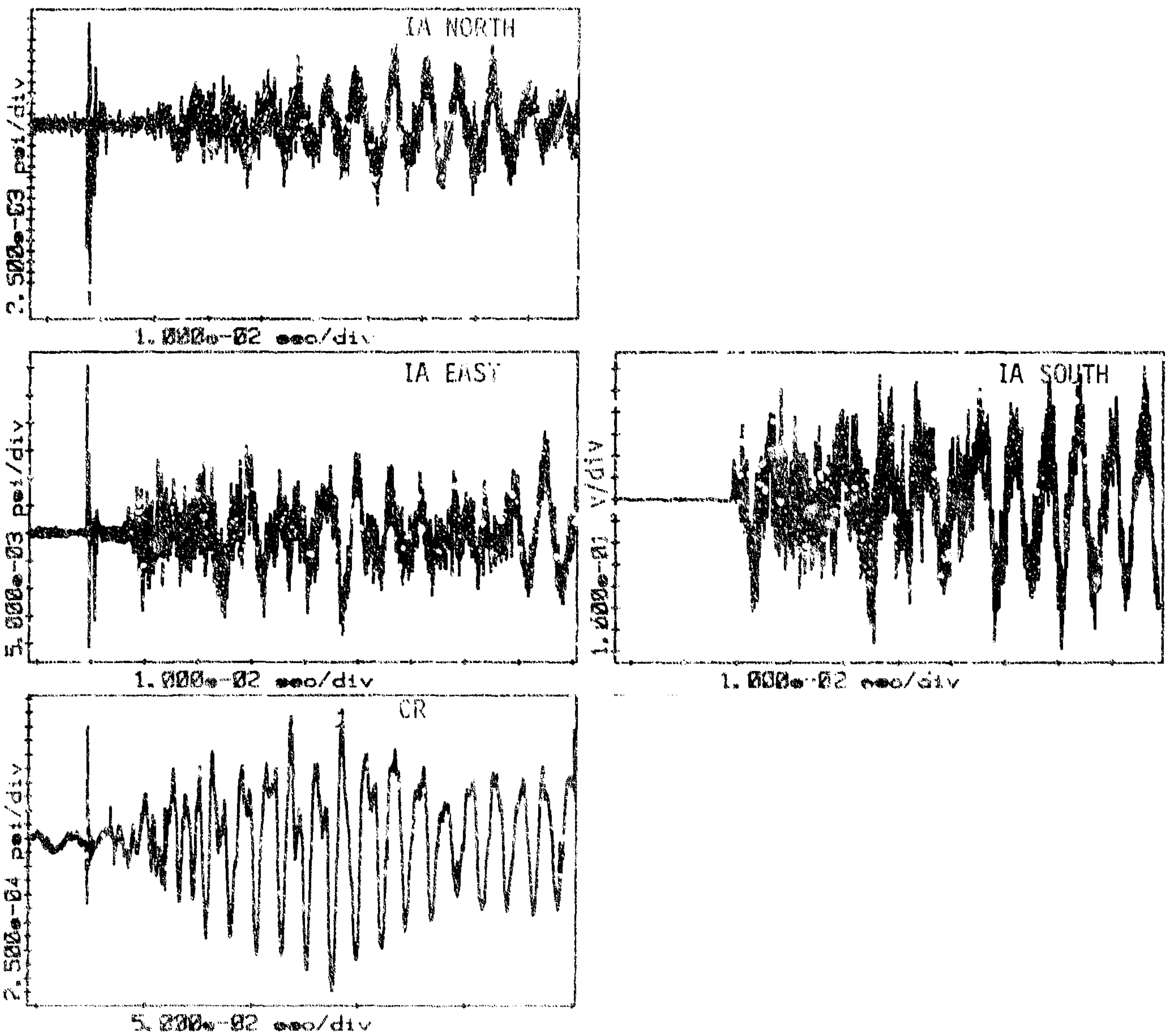


FIGURE C-9. SOUND LEVEL READINGS FOR SHOT 2310

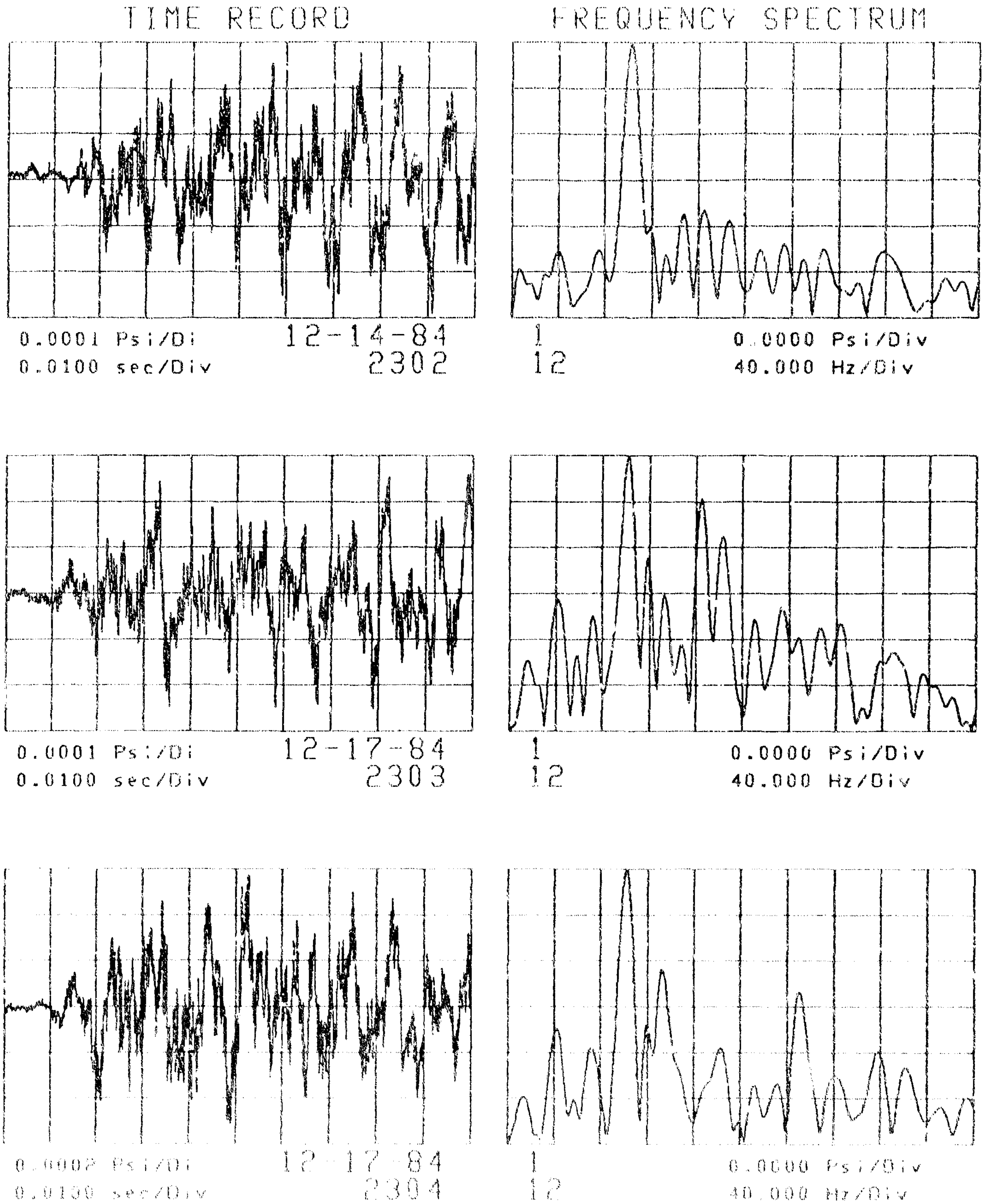


FIGURE C-10. FREQUENCY SPECTRUM ANALYSIS HISTORIES FOR SOUND LEVEL GAUGE WA-2

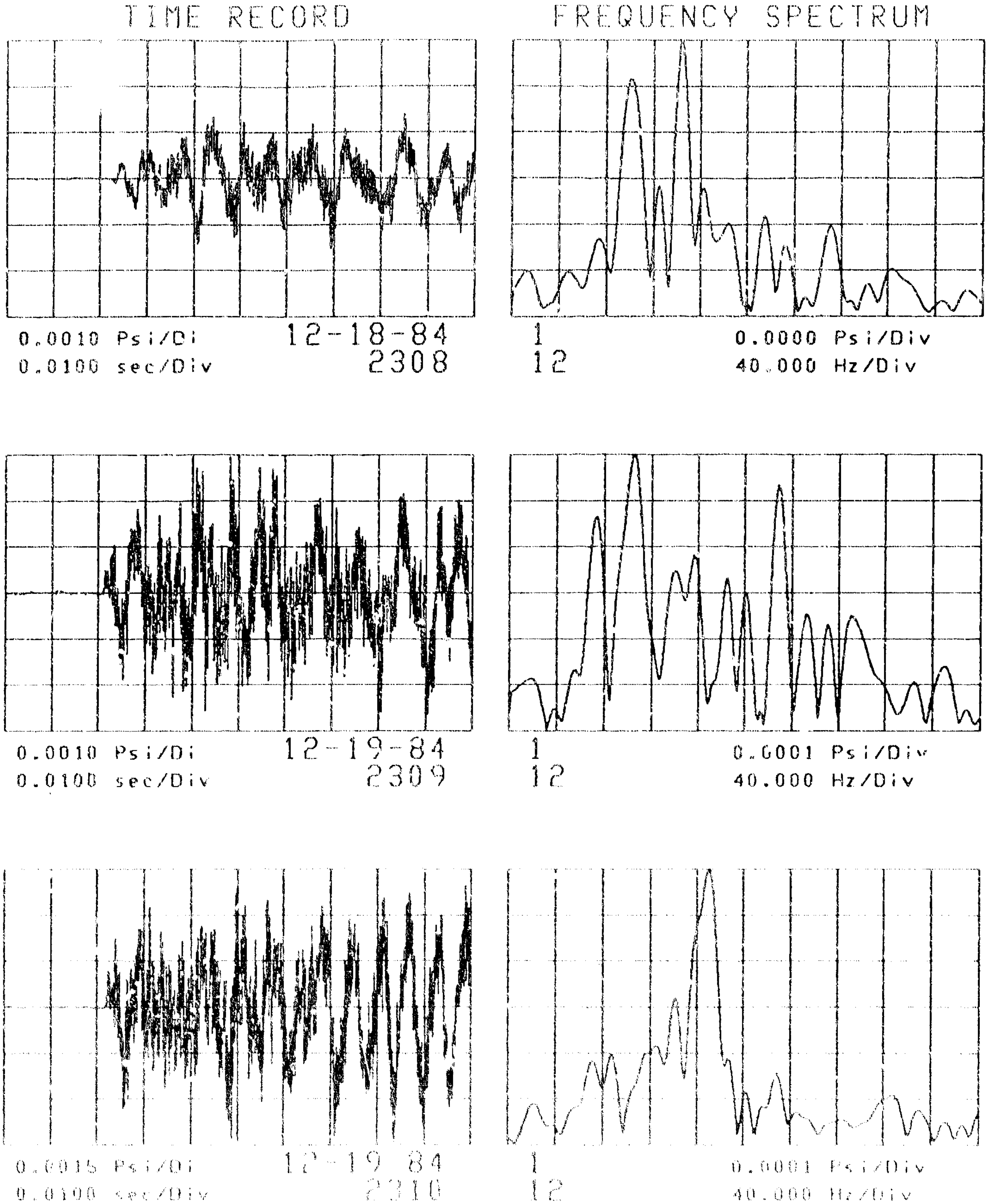
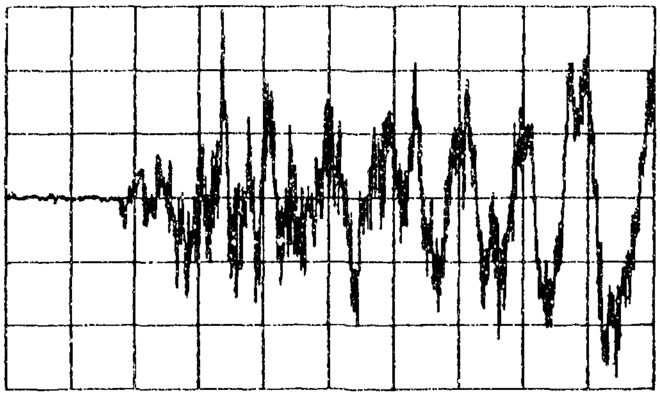


FIGURE C-10. FREQUENCY SPECTRUM ANALYSIS HISTORIES FOR SOUND LEVEL GAUGE WA-2 (Cont.)

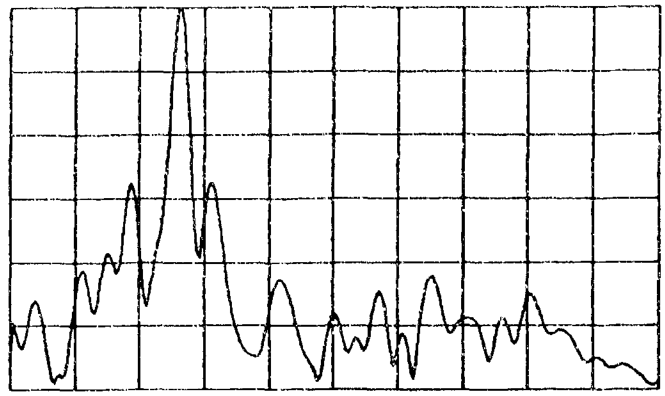
TIME RECORD

FREQUENCY SPECTRUM



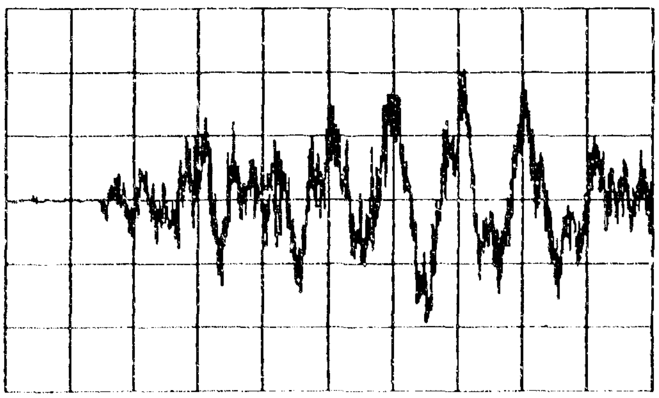
0.0002 Psi/Di
0.0100 sec/Div

12-17-84
2305



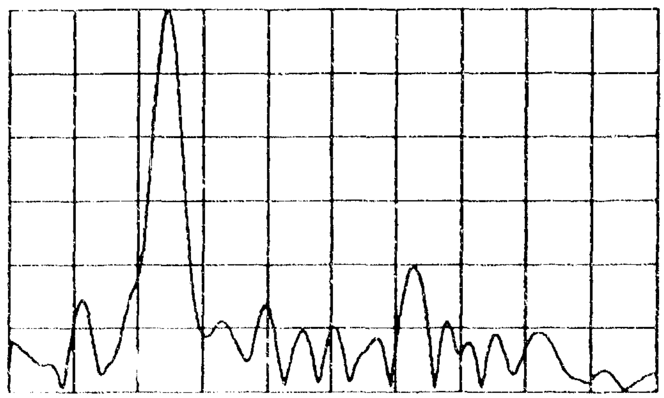
1
12

0.0000 Psi/Div
40.000 Hz/Div



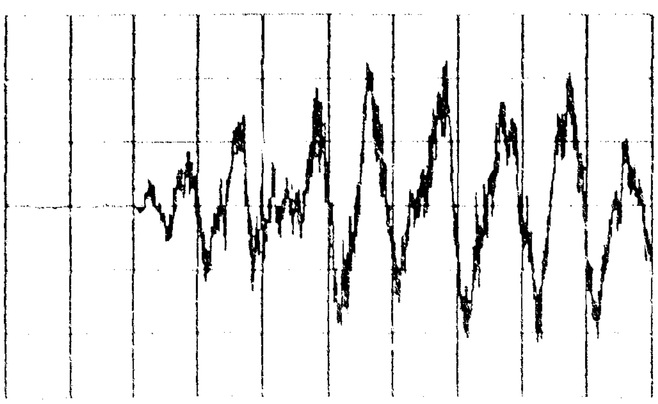
0.00075 Psi/Di
0.0100 sec/Div

12-17-84
2306



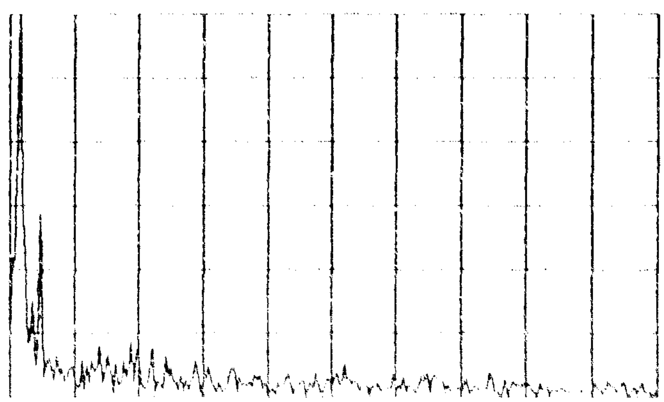
1
12

1.3008 Psi/Div
40.000 Hz/Div



0.0005 Psi/Di
0.2500 sec/Div

12-17-84
2307



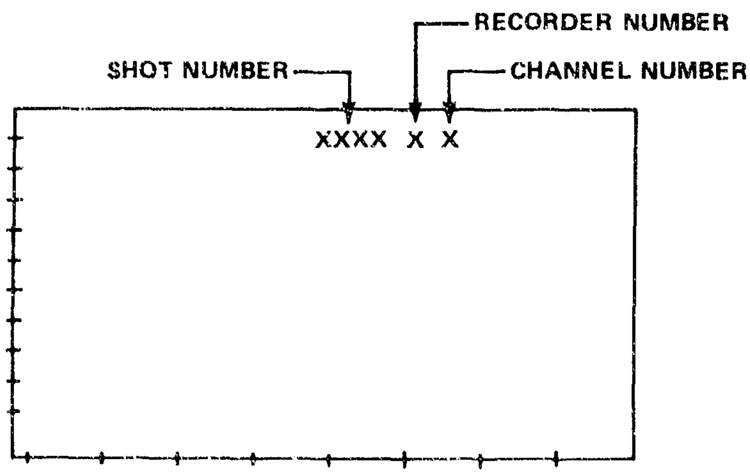
1
12

0.0000 Psi/Div
40.000 Hz/Div

FIGURE C-13. FREQUENCY SPECTRUM ANALYSIS HISTORIES FOR SOUND LEVEL GAUGE WA 2 (Cont.)

APPENDIX D

PRESSURE-TIME HISTORIES FOR MEASUREMENTS INSIDE BLAST CHAMBER



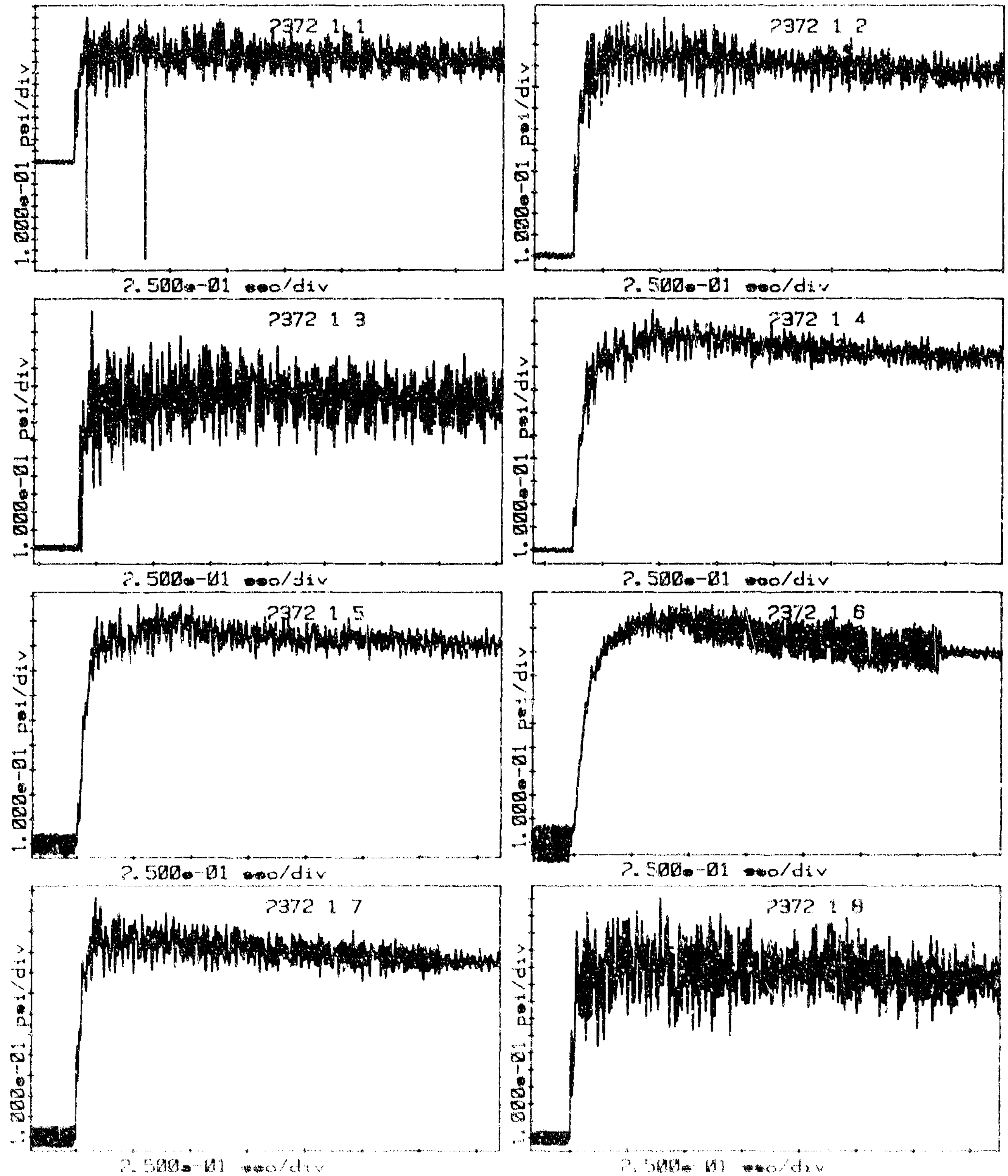


FIGURE D-1. PRESSURE TIME HISTORIES FOR SHOT 2372

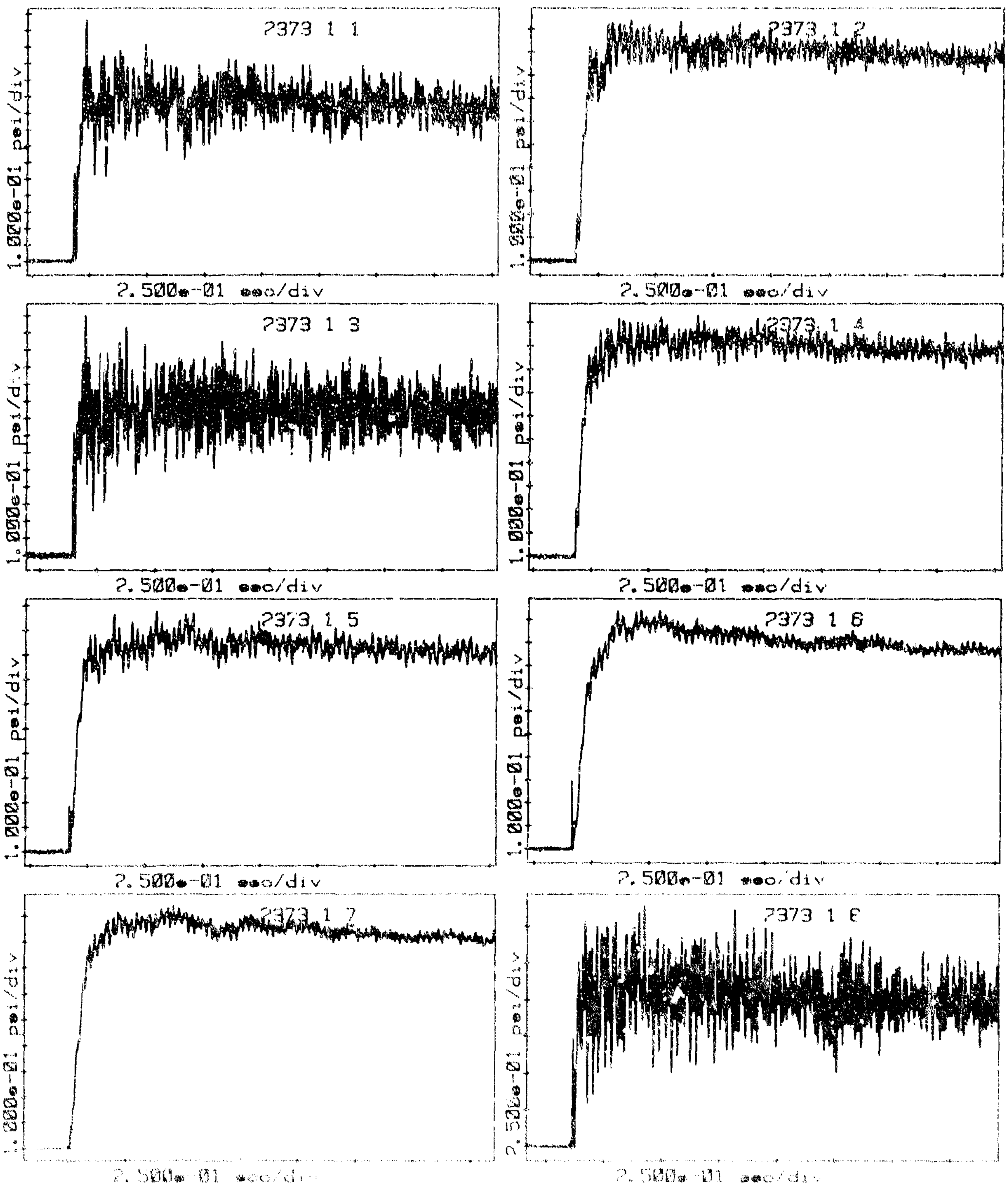


FIGURE D-2. PRESSURE TIME HISTORIES FOR SHOT 2373

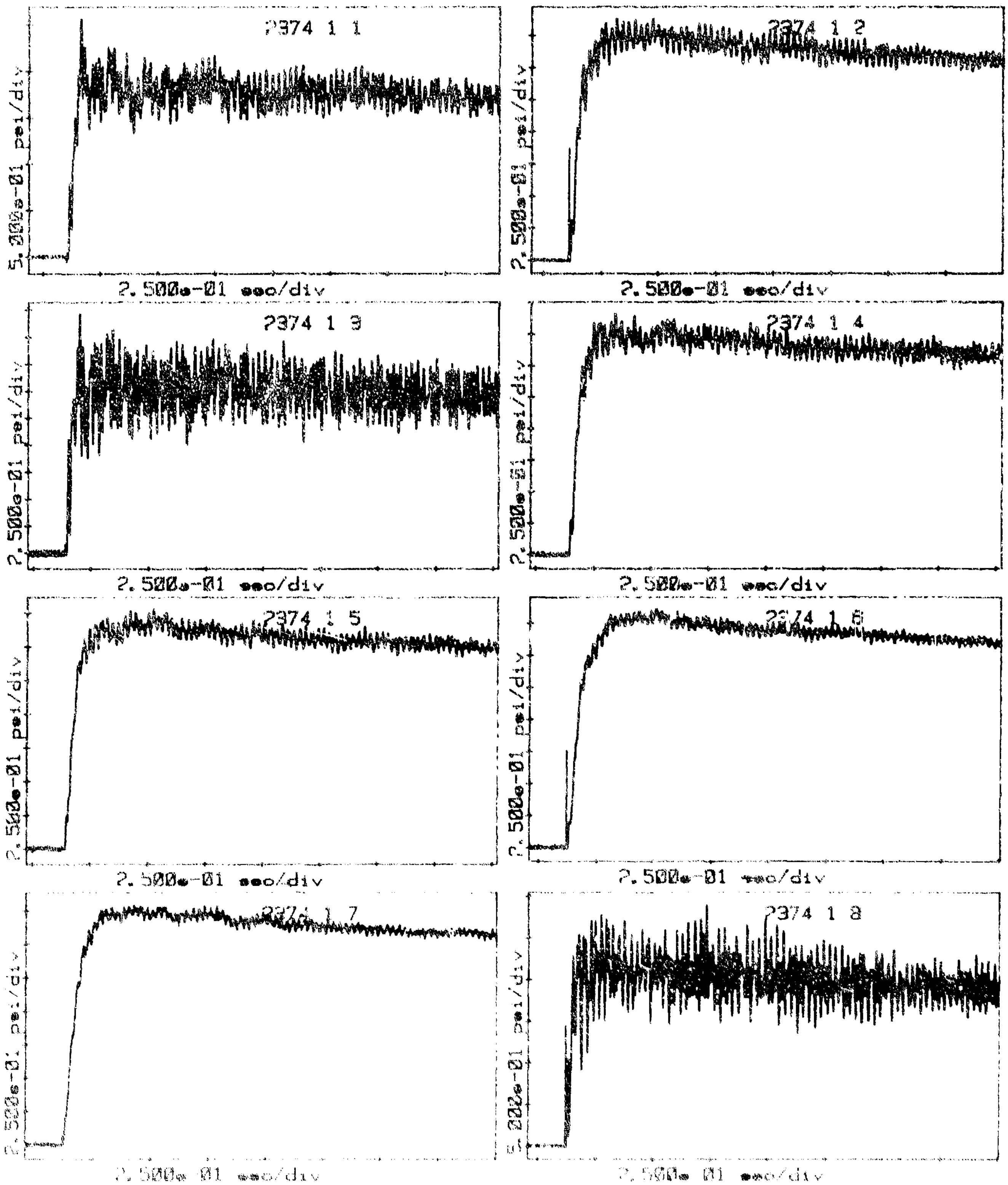


FIGURE D-3 PRESSURE TIME HISTORIES FOR SHOT 2374

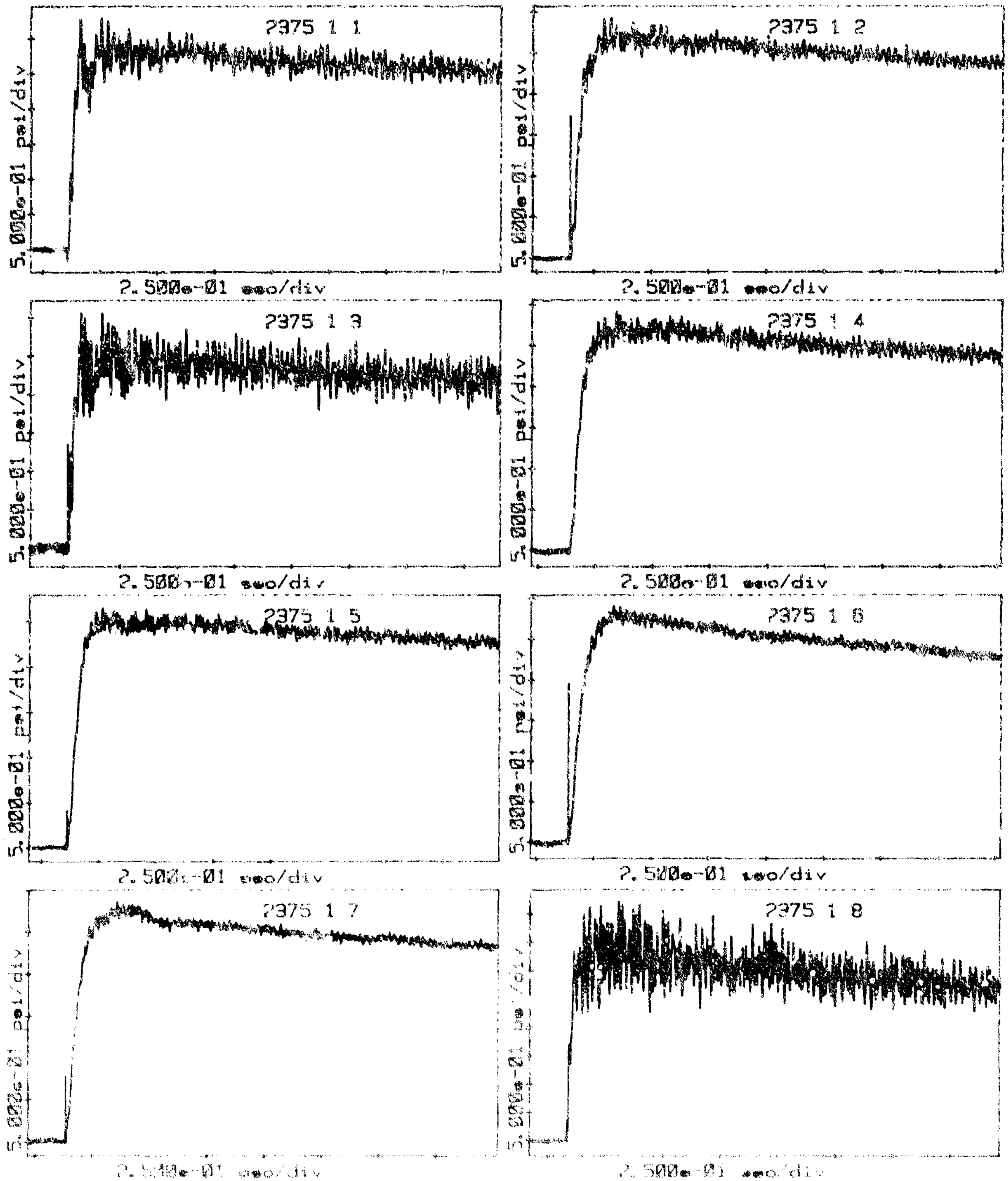


FIGURE D-4 PRESSURE-TIME HISTORIES FOR SHOT 2375

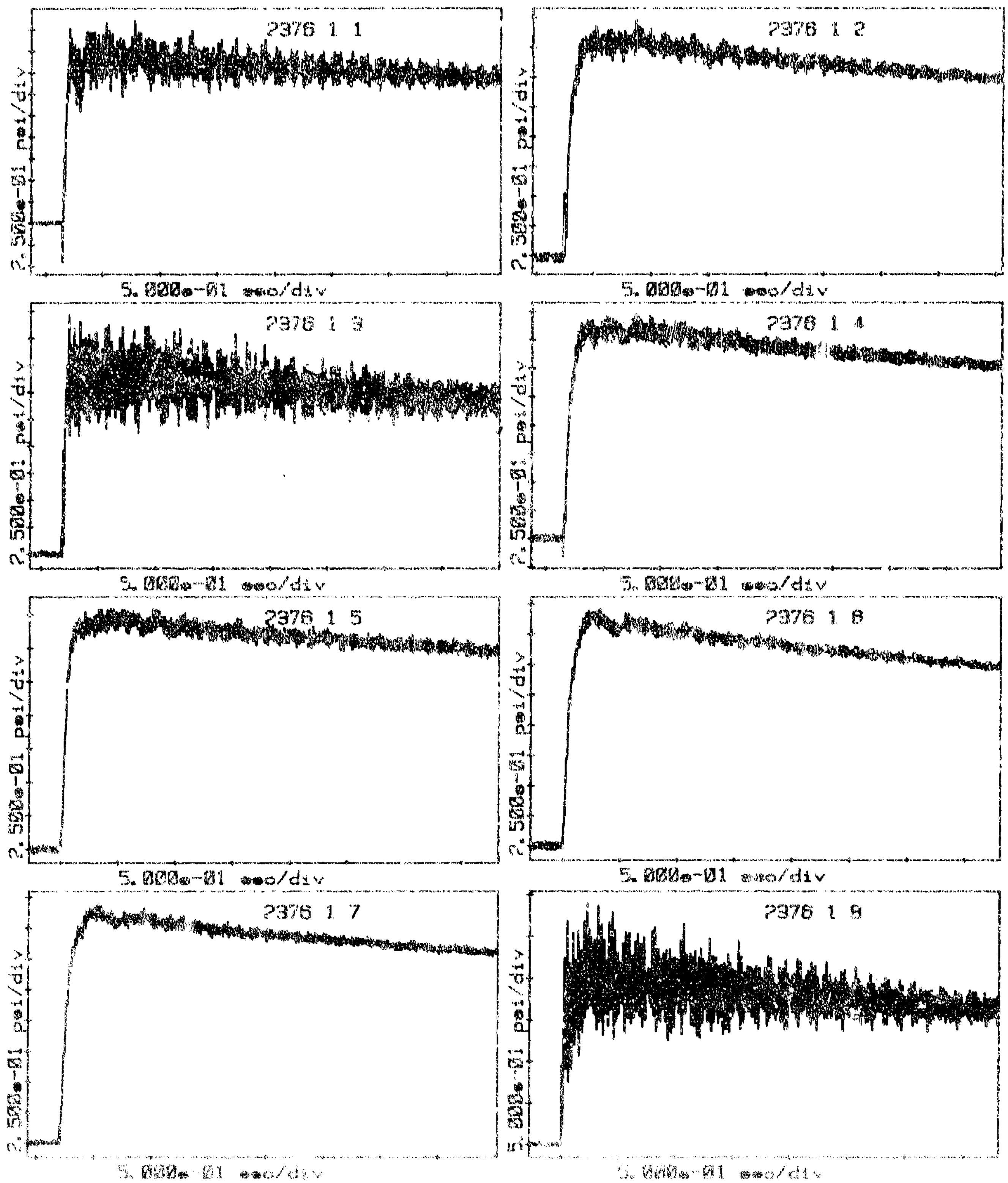


FIGURE D-5. PRESSURE-TIME HISTORIES FOR SHOT 2376

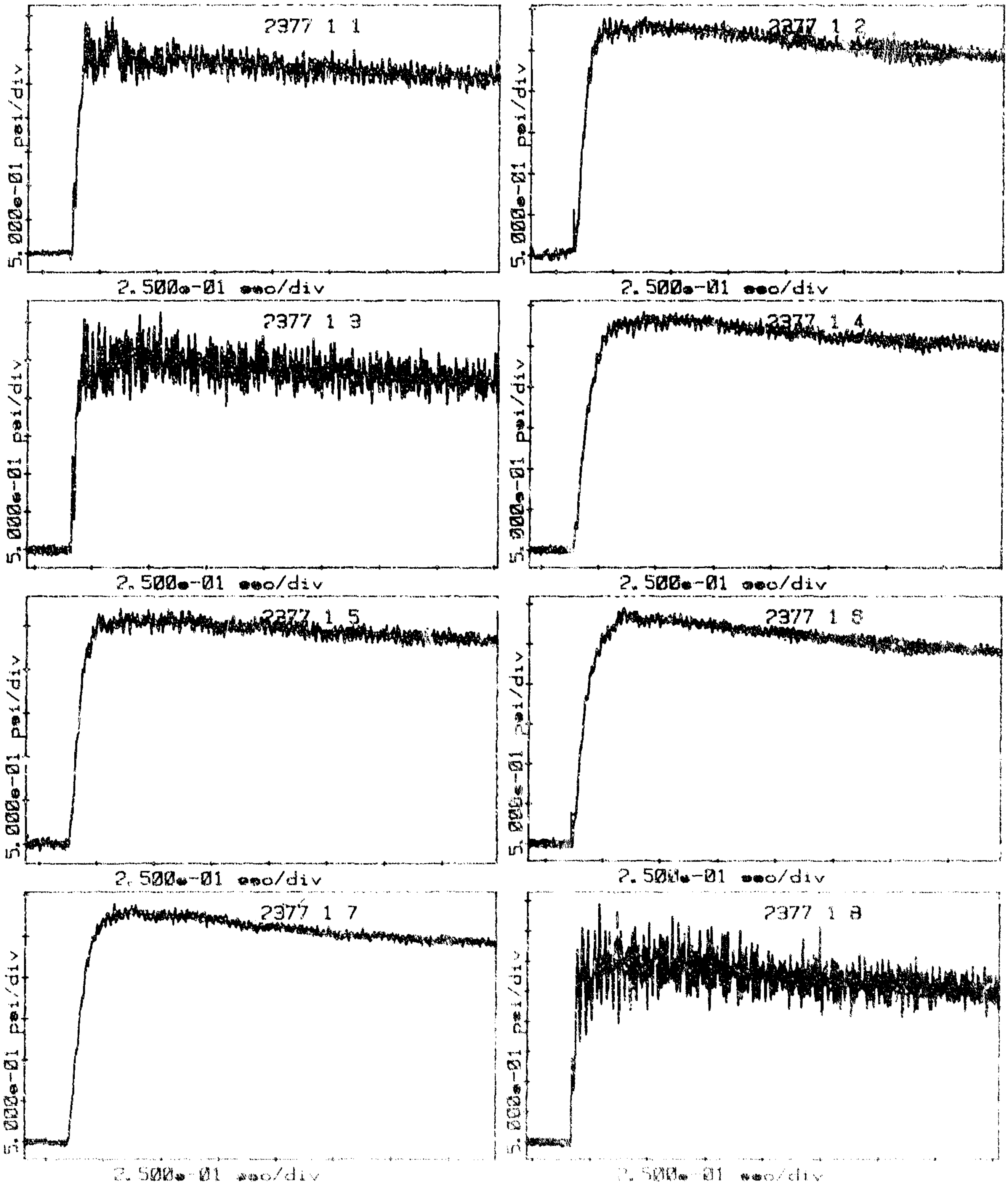


FIGURE D-6. PRESSURE-TIME HISTORIES FOR SHOT 2377

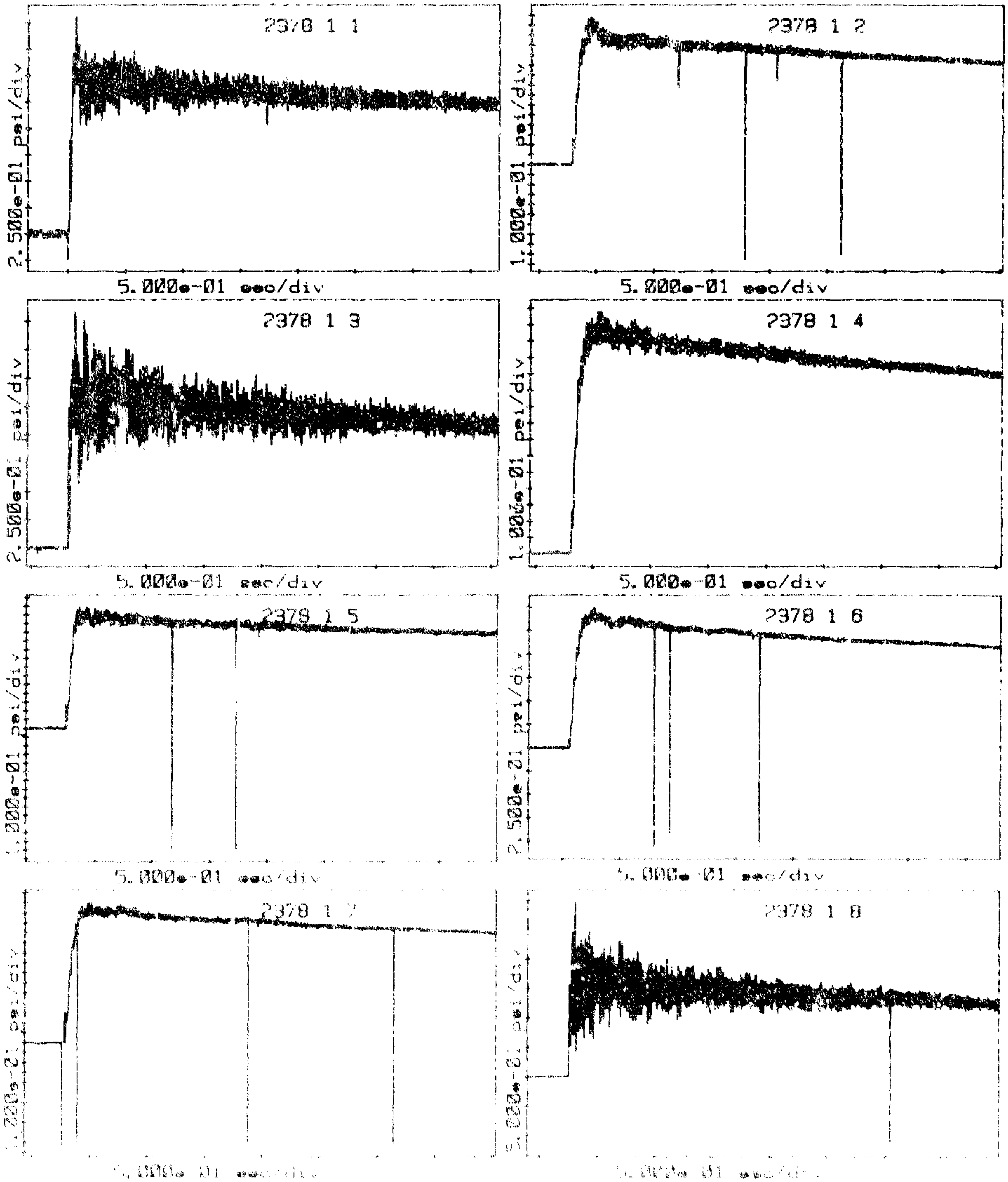


FIGURE D-7 PRESSURE TIME HISTORIES FOR SHOT 2378

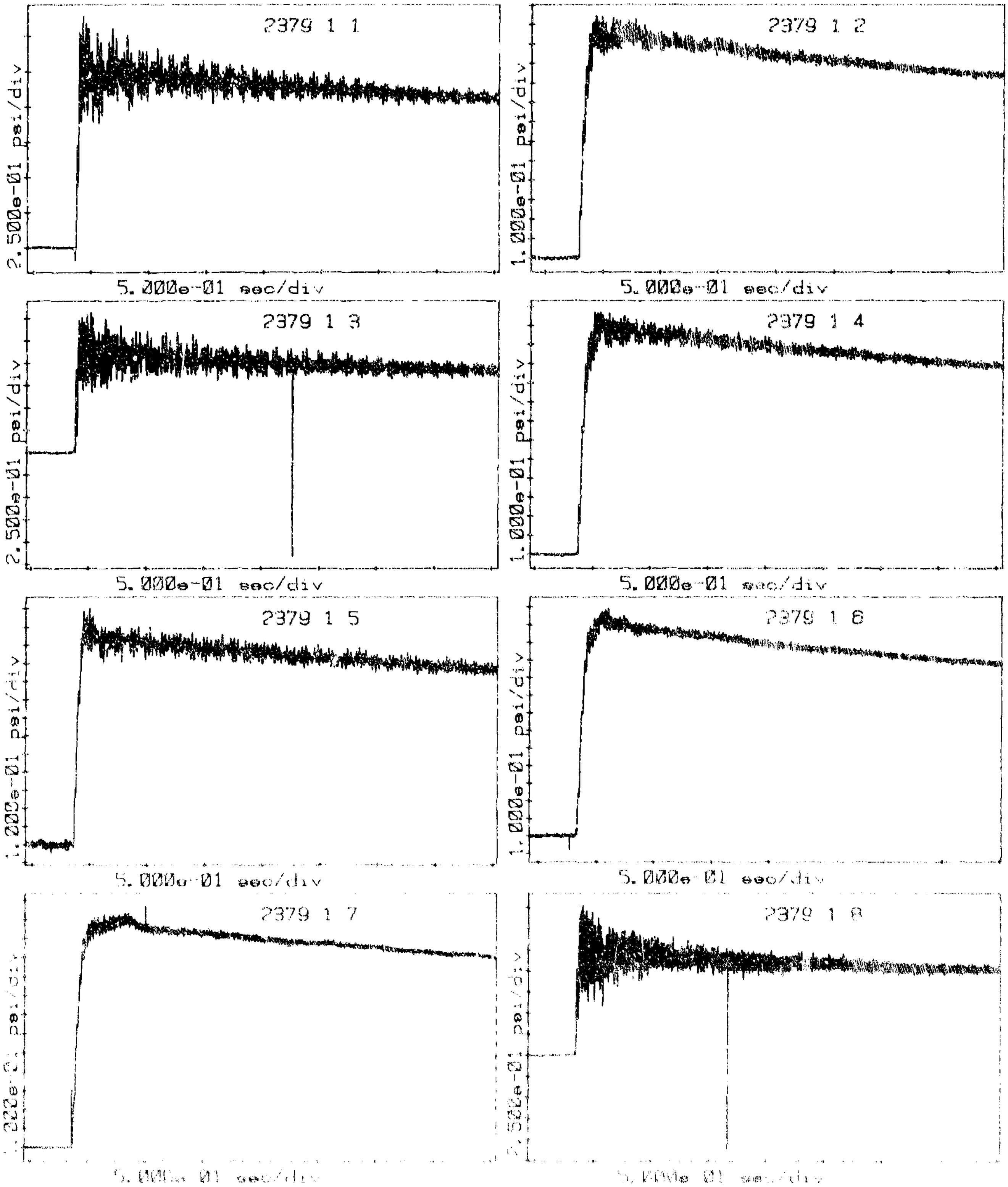


FIGURE D-8. PRESSURE TIME HISTORIES FOR SHOT 2379

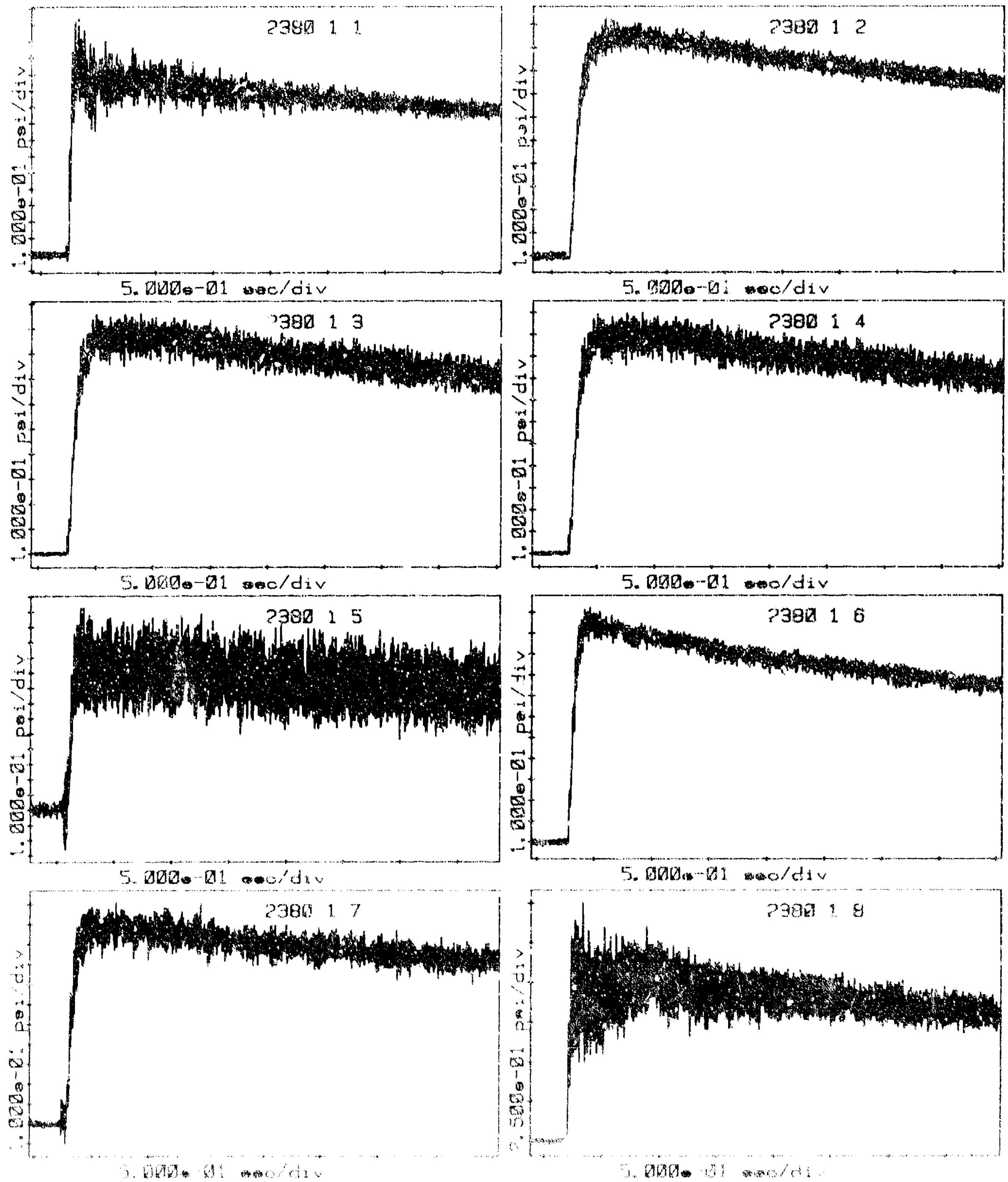


FIGURE C-8. PRESSURE TIME HISTORIES FOR SHOT 2380

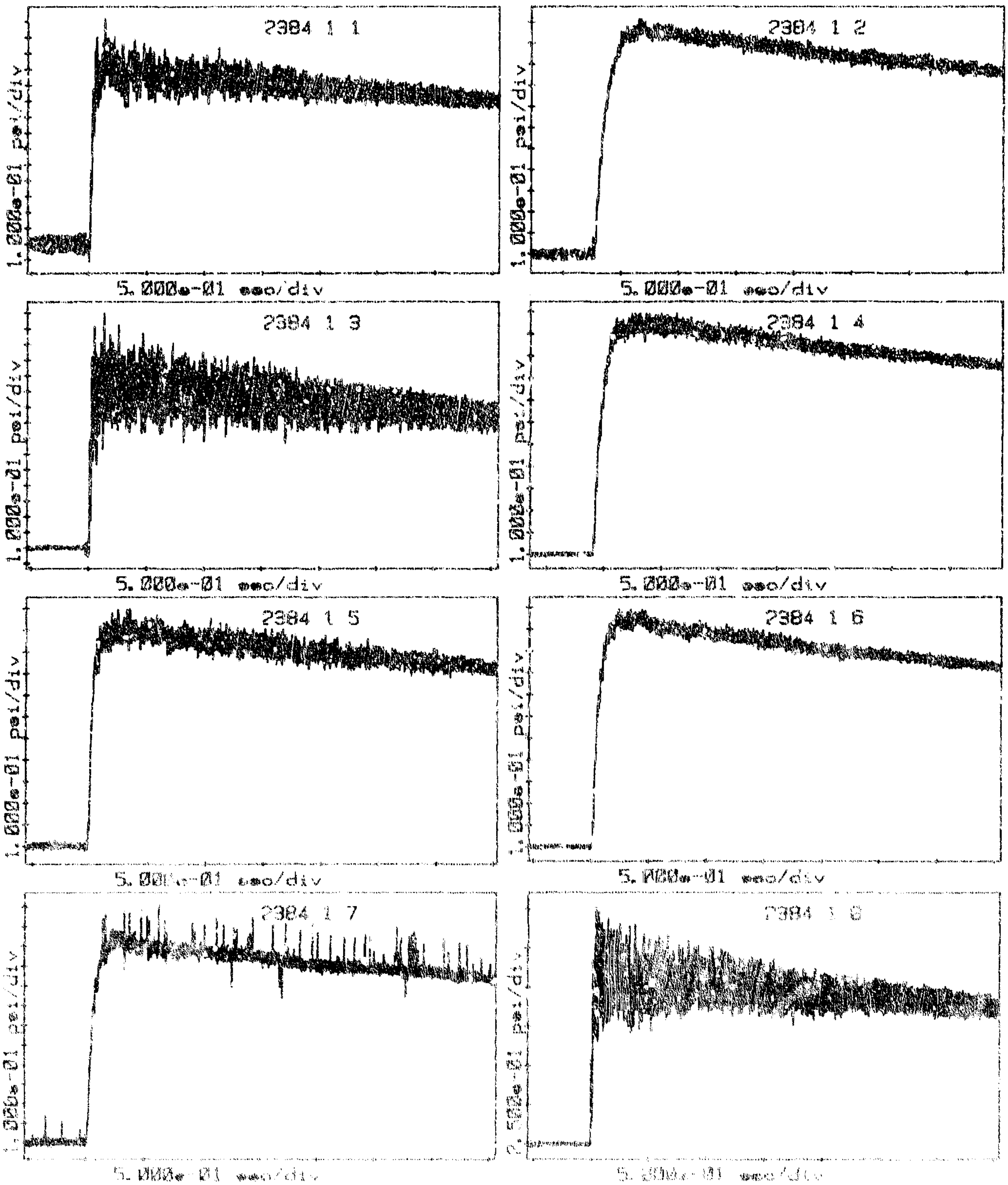


FIGURE D-10. PRESSURE-TIME HISTORIES FOR SHOT 2384

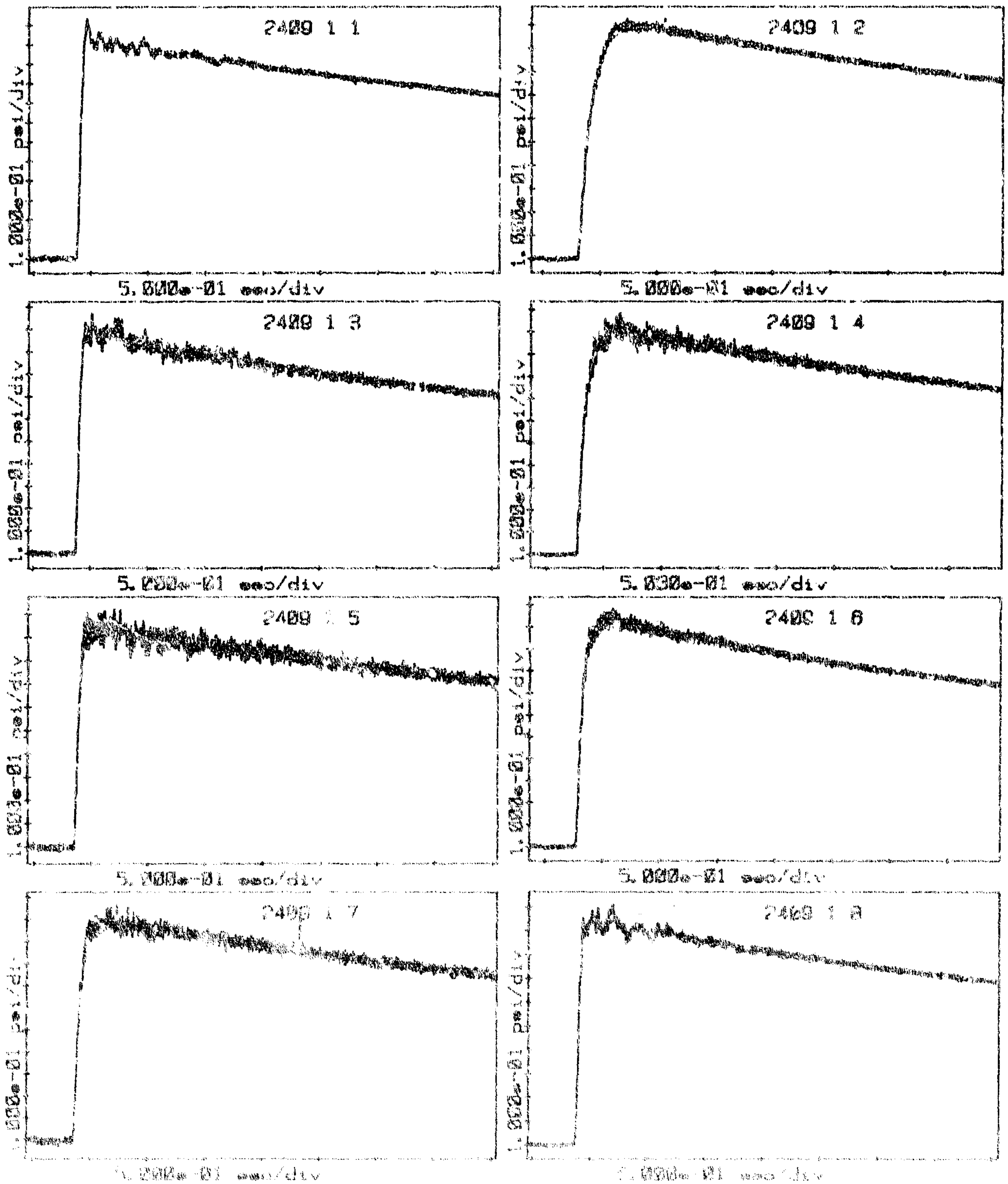


FIGURE D-11 PRESSURE TIME HISTORIES FOR SHOT 2409

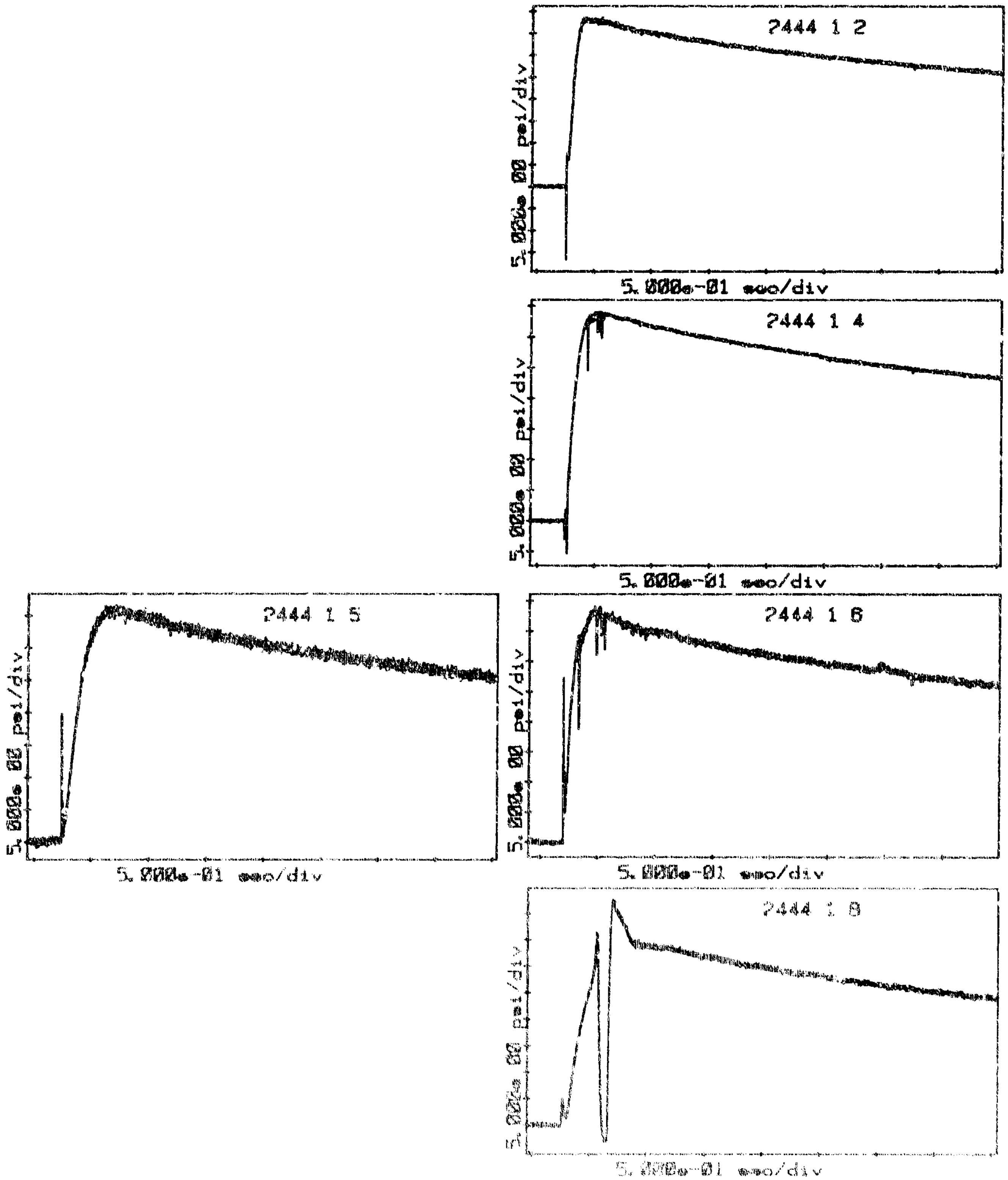
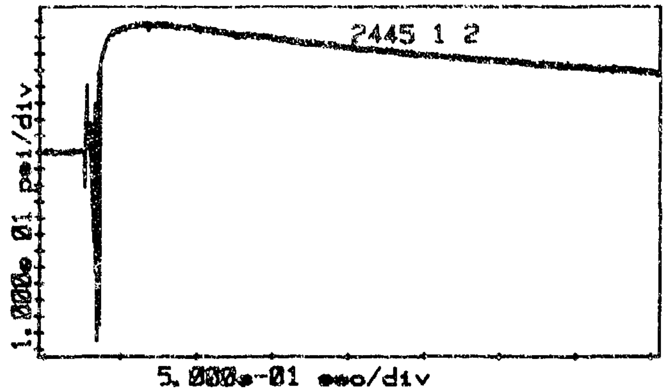
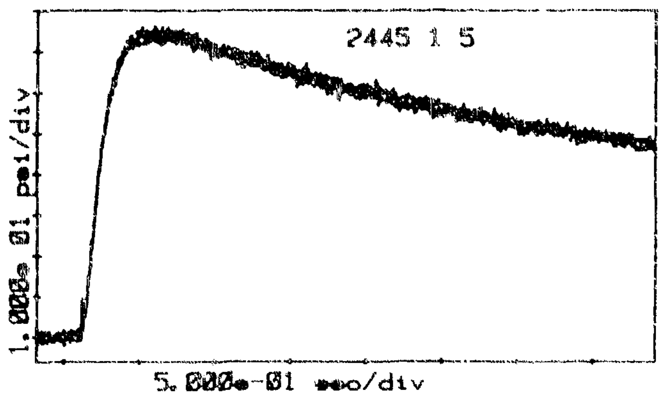


FIGURE D-12. PRESSURE-TIME HISTORIES FOR SHOT 2444





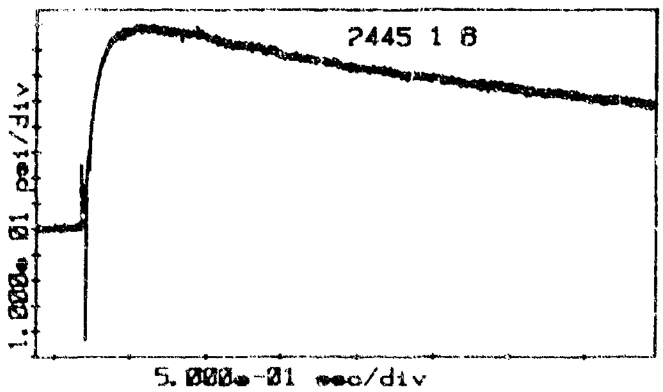


FIGURE D-13. PRESSURE-TIME HISTORIES FOR SHOT 2445

APPENDIX E

ACCELERATION-TIME HISTORIES

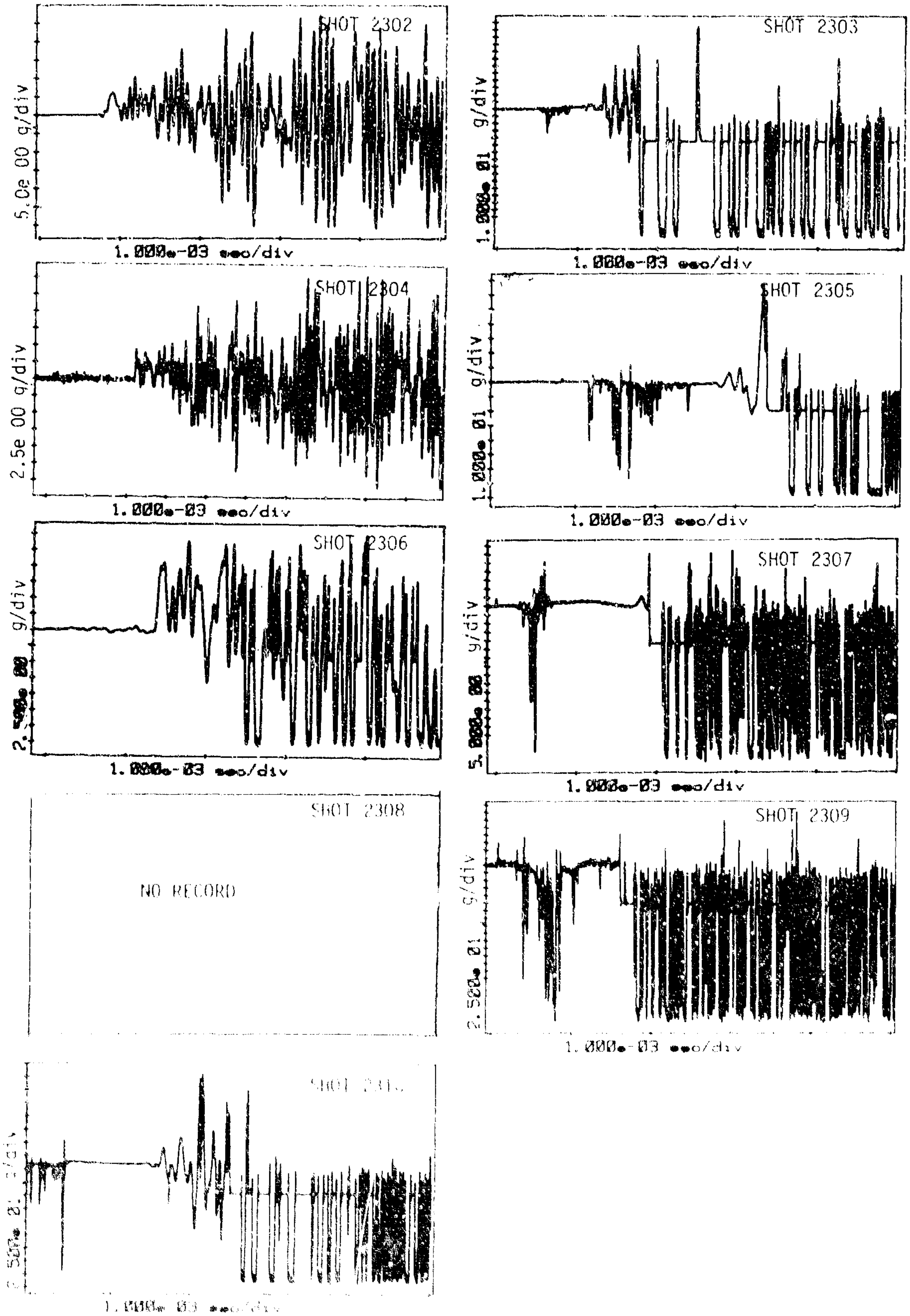


FIGURE E-1. ACCELERATION TIME HISTORIES OF GAUGE MOUNTED ON DOOR OF BLAST CHAMBER

APPENDIX F

STRAIN-TIME HISTORIES

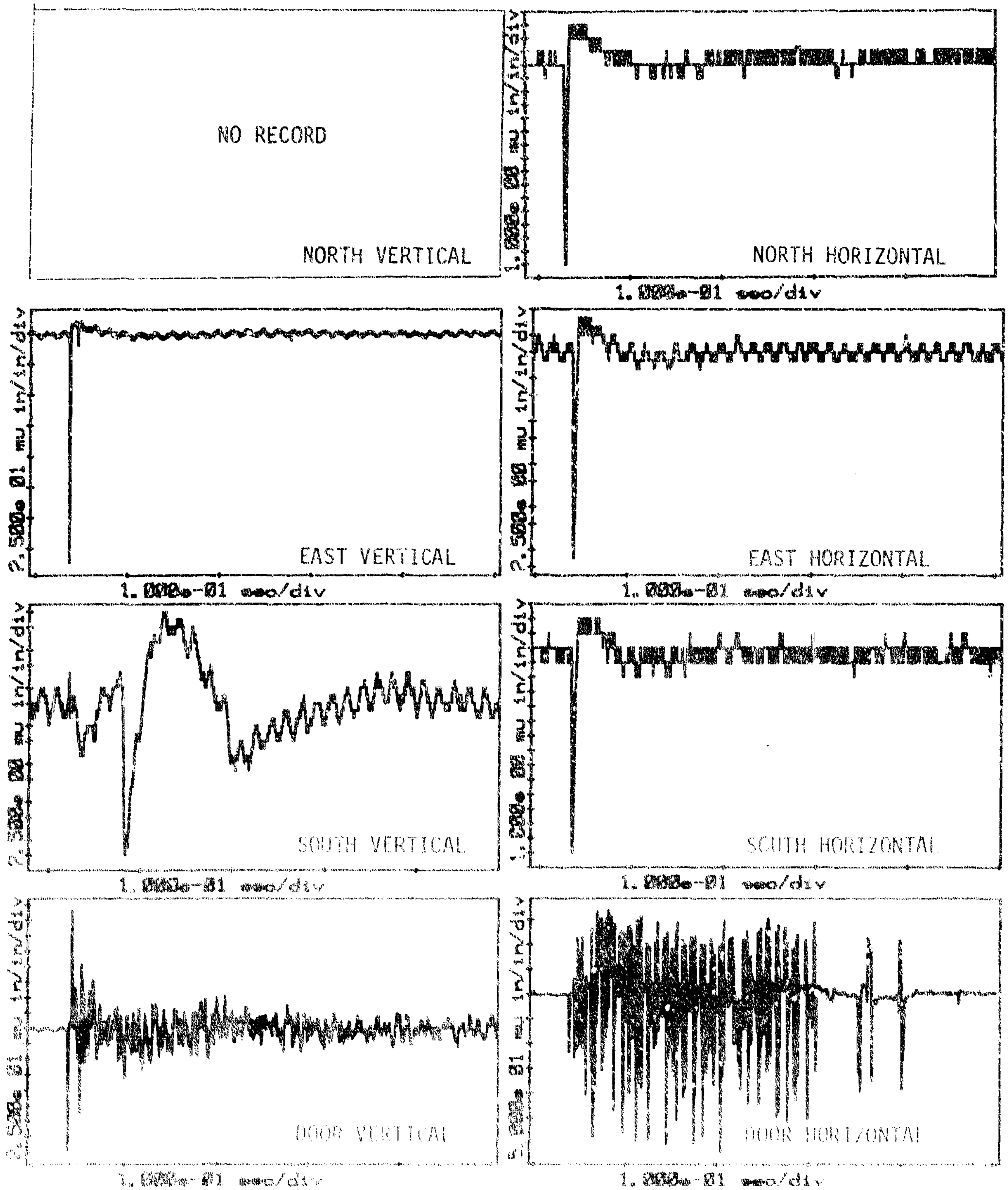


FIGURE F-[illegible] STRAIN TIME HISTORIES FOR SHOT 2302

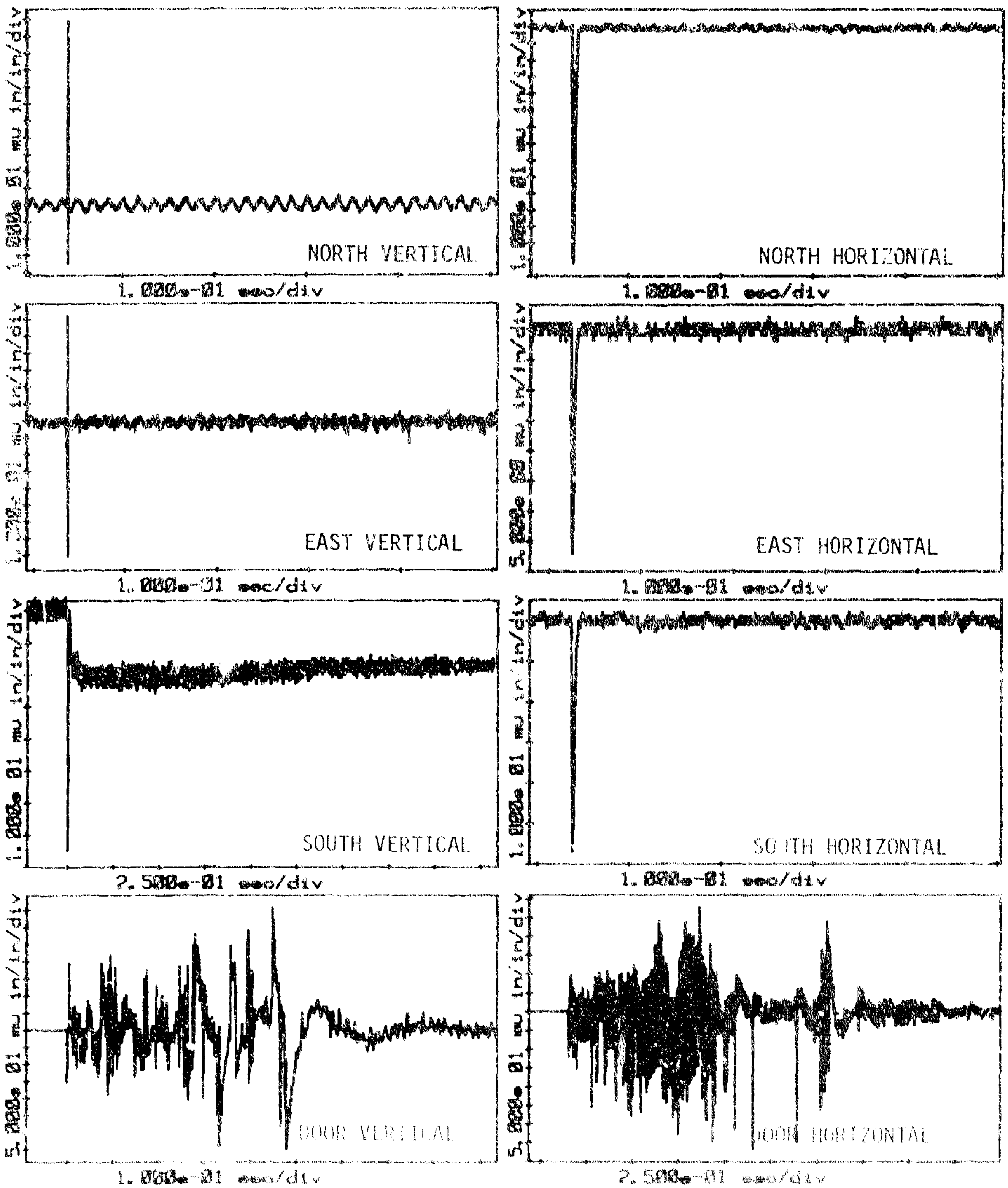


FIGURE E-2. STRAIN TIME HISTORIES FOR SHOT 2303

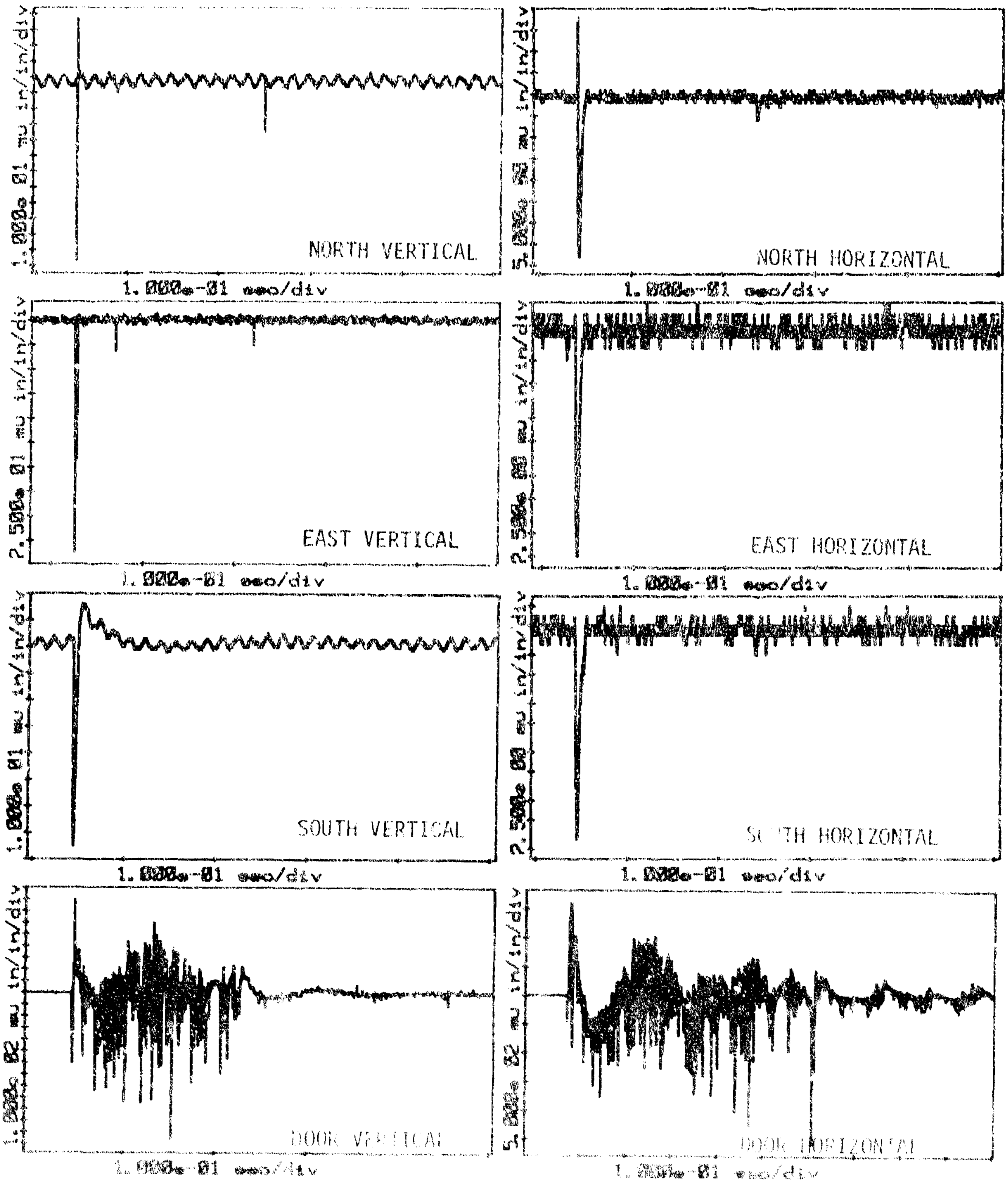


FIGURE F-3. STRAIN TIME HISTORIES FOR SHOT 2304

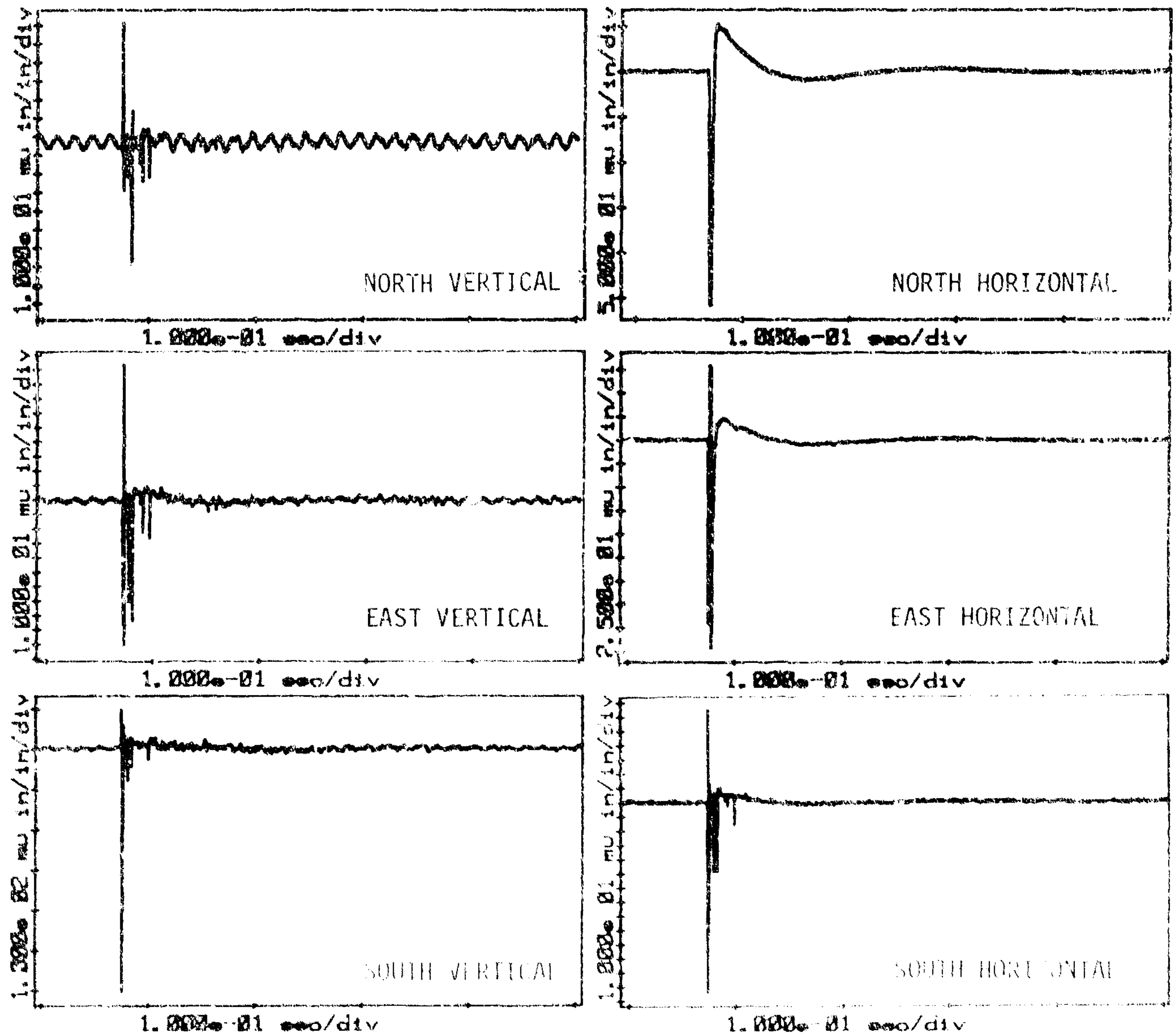


FIGURE E-4. STRAIN-TIME HISTORIES FOR SHOT 2305

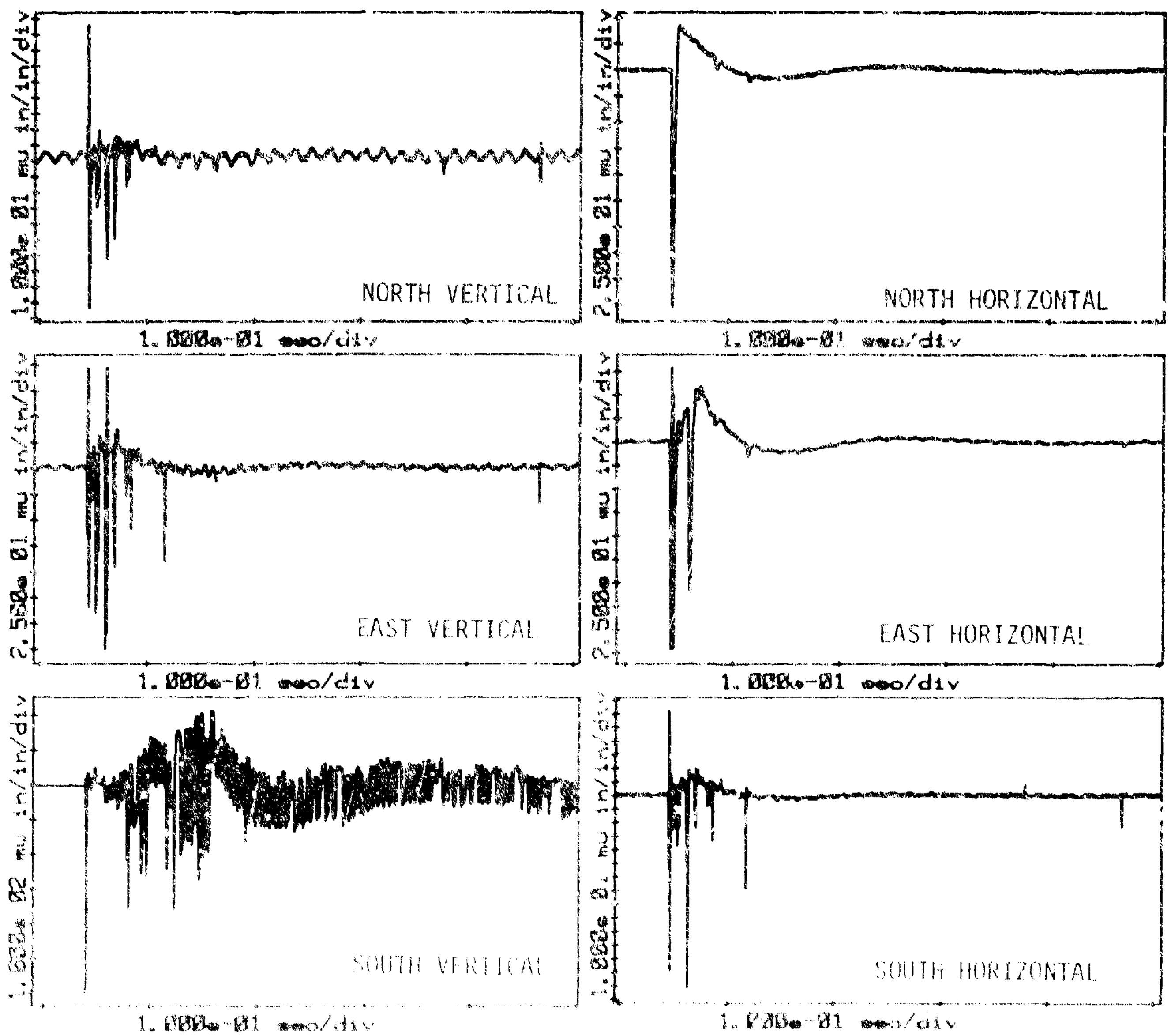


FIGURE F-5. STRAIN-TIME HISTORIES FOR SHOT 2306

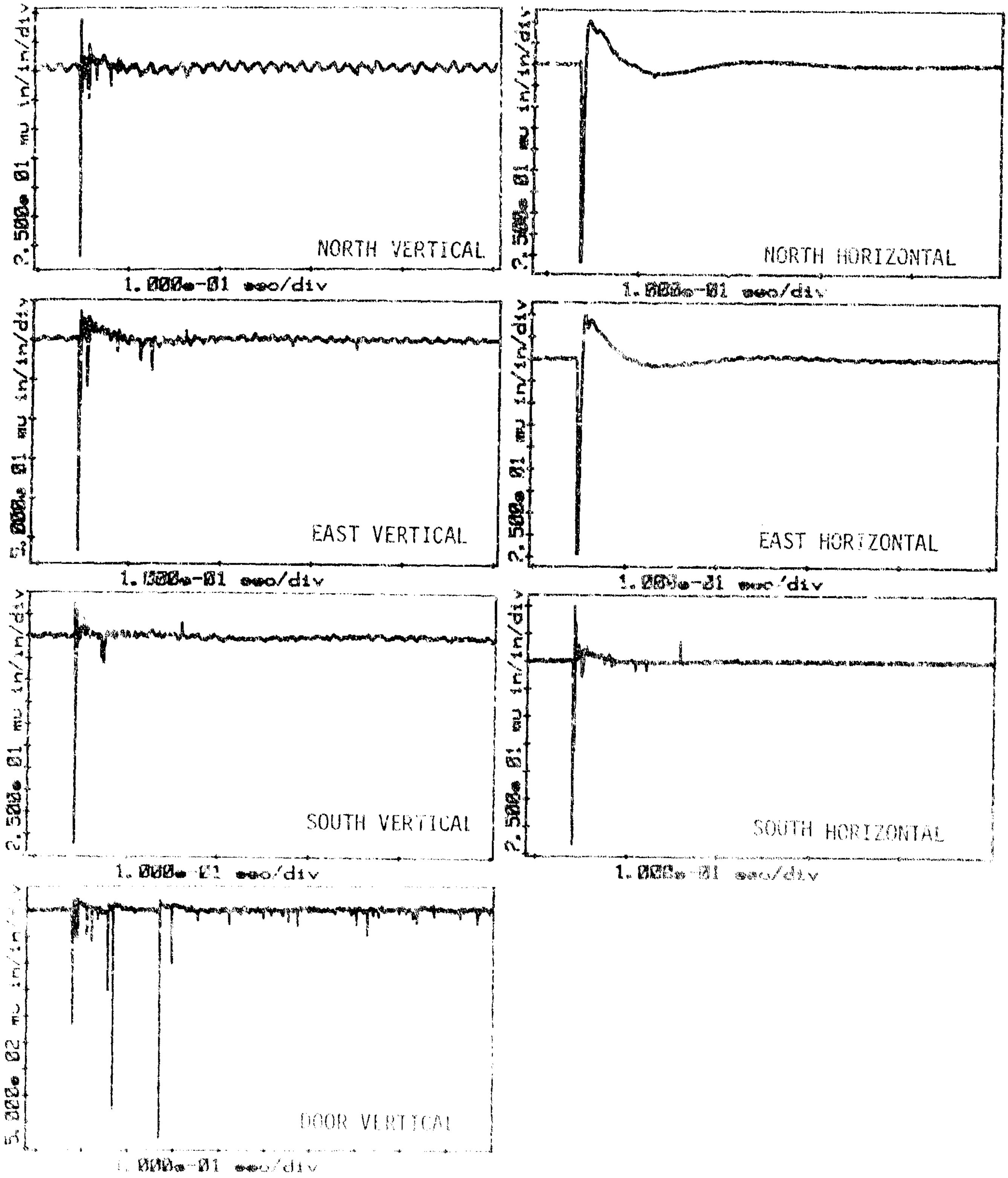


FIGURE F-6 STRAIN TIME HISTORIES FOR SHOT 2307

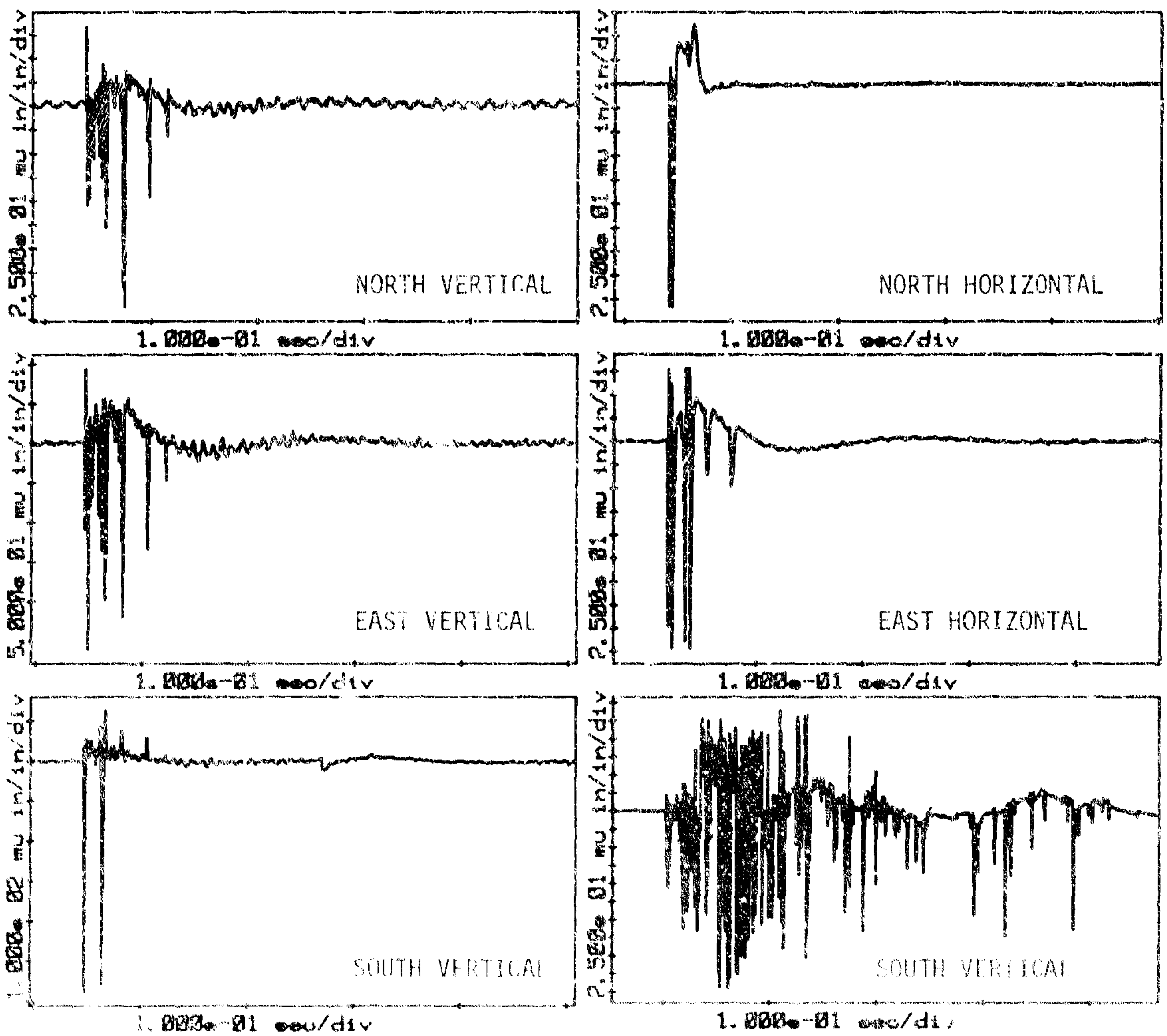


FIGURE E-7. STRAIN TIME HISTORIES FOR SHOT 2308

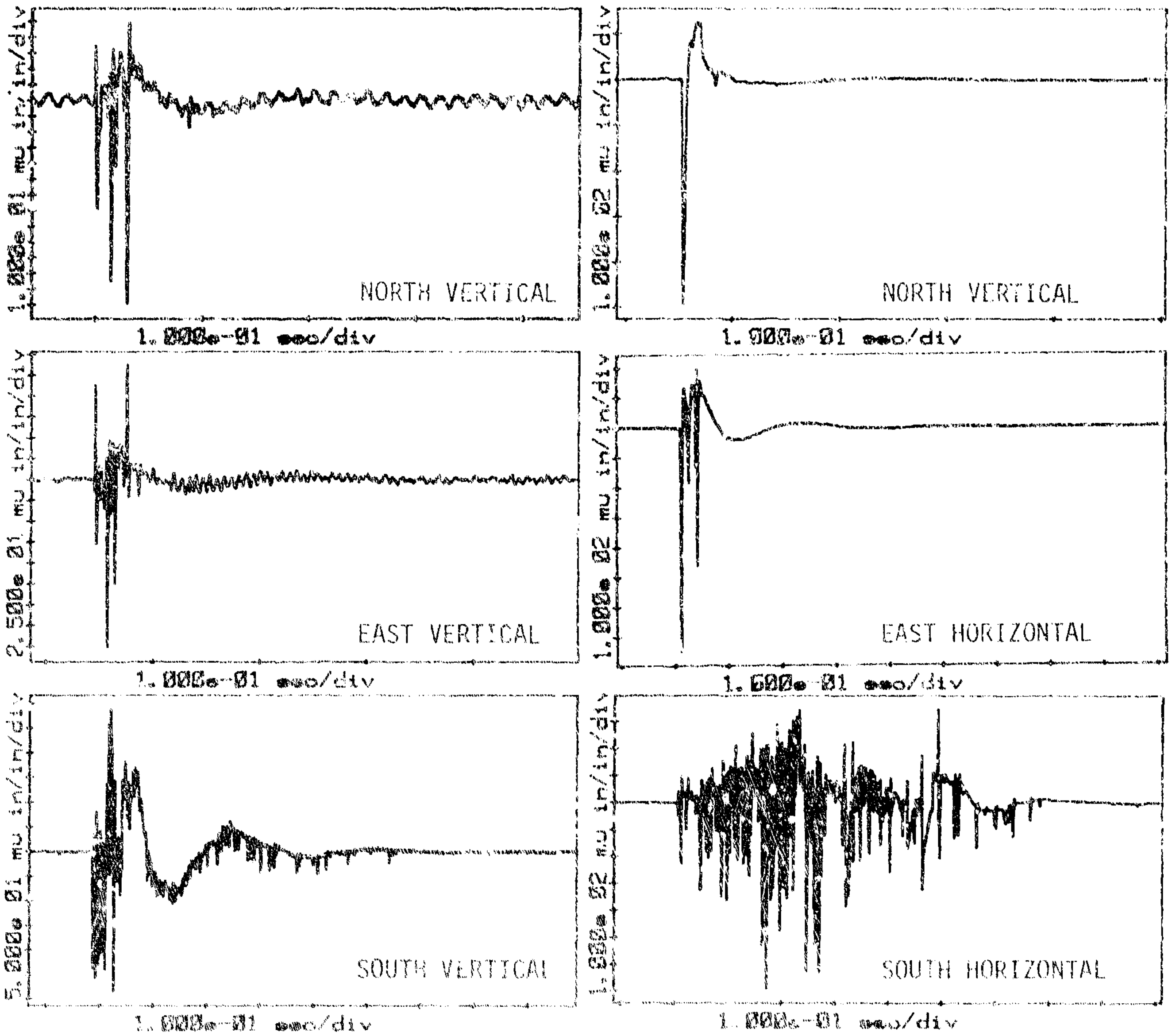


FIGURE F-8. STRAIN-TIME HISTORIES FOR SHOT 2309

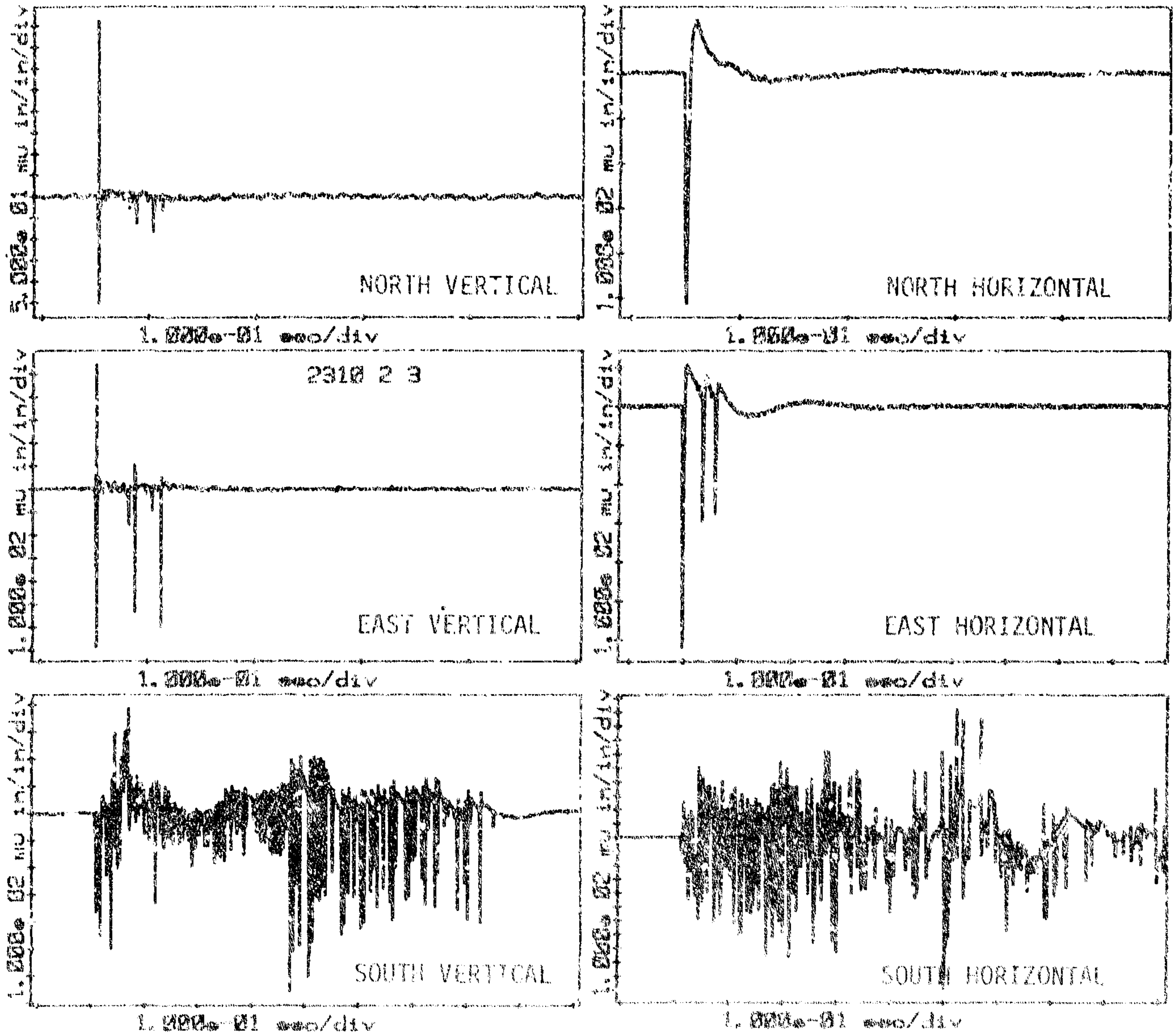


FIGURE F-9. STRAIN TIME HISTORIES FOR SHOT 2310

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